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Instruction Manual

980242

MODEL 2860 DATA AMPLIFIER

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INSTRUCTION MANUAL

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MODEL 2860

DATA AMPLIFIER

DANA LABORATORIES, INC.
2401 CAMPUS DRIVE
IRVINE, CALIFORNIA 92664

DANA®

TELEPHONE (714) 833-1234
TELETYPE 910-595-1136
TELEX 678-341

August, 1967

Revised October, 1971

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SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

The Dana Model 2860 is a passive-guard differential amplifier with low noise at gains up to 2500, high level of common mode rejection, and fast settling time. Full-scale output is ±10 volts and ±100 milliamperes.

The Model 2860 features the advantages of direct-coupled amplifiers (linearity, low zero drift, low noise) with the 300-volt common mode operating capability that is characteristic of modulation-coupled amplifiers.

A front-panel bandwidth control allows the output to be set at any one of five selected bandwidths: 10Hz, 100Hz, 1kHz, 10kHz and wideband. The wideband 3dB point is 50kHz.

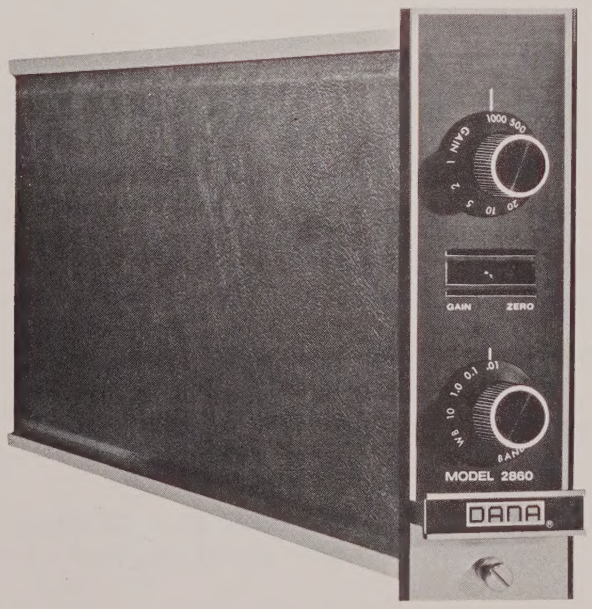


Figure 1.1 - Model 2860 Data Amplifier

The input, output, and power supply of the Model 2860 contain RF interference suppression from external RF noise. The Model 2860 provides almost complete isolation between the input leads and output common. If desired, the Model 2860 may also be used as a single ended unit, inverting or non-inverting, in applications in which either the source or the load is isolated from the ground. The common-mode rejection is 120dB, dc to 60 Hz.

Circuits within the amplifier prevent damage from short circuits and from fault voltages up to 30 volts normal mode.

System noise contributed by the amplifier circuitry is exceptionally low. The noise referred to the input (RTI) at a gain of 1000 is less than 5 microvolts rms in full bandwidth and less than 1 microvolt, peak-to-peak, in a 10Hz bandwidth.

1.2 OPERATIONAL DESCRIPTION

A block diagram of the Model 2860 is shown in Figure 1.2. The Preamplifier amplifies the normal mode signal. The amplified signal is modulated and applied to the isolation transformer, demodulated, and further amplified by the Output Amplifier. The common mode potential (E_{CM}) appears between the transformer shields. The input guard or shield surrounds the Preamplifier as well as the input leads. When the guard is referenced to the common mode potential, the

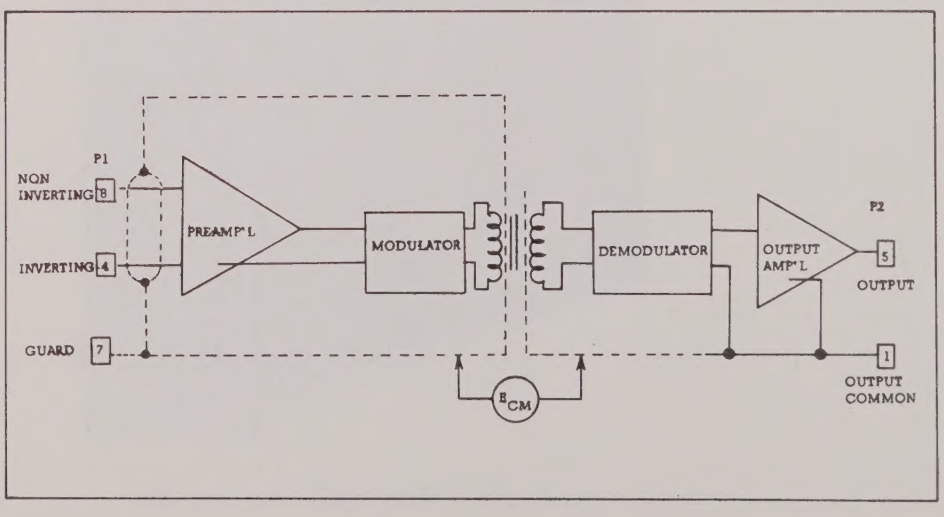


Figure 1.2 - Block Diagram, Model 2860

common mode potential is isolated from the preamplifier achieving the high common mode rejection required for data amplifiers. The passive guard or passive shield can reject a greater magnitude of common-mode voltage than the active-guard amplifiers and is characterized by constant common mode rejection - not affected by gain setting.

The Output Amplifier contains an operational amplifier and an active-admittance amplifier. The output voltage of the Output amplifier is ± 10 volts across a 100 ohm load.

Capacitors in the active-admittance filter are switched with each position of the BANDWIDTH switch to set the upper limit of each bandwidth.

Precision resistors in the Preamplifier are switched with each position of the GAIN switch to set the gain of the amplifier. A vernier extends each range equal to 2-1/2 times the nominal gain setting.

A more detailed description of the circuits of the Model 2860 is given in Section 4 - Circuit Description.

1.3 GAIN OPTIONS

Two gain options are available and must be specified when ordering the amplifier. They are designated as gain options V4 and V5. The Models 2860 V4 and 2860 V5 are especially suited in applications where low-level, millivolt signals are to be amplified to voltage levels for accurate recording or measuring and in applications where common mode potentials are greater than 10 volts dc or peak ac.

1.3.1 Option V4

The V4 option provides gain steps of 1, 2, 5, 10, 20, 50, 100, 200, 500, and 1000. A vernier multiplier extends each gain by a factor of 2.5:1. Gain accuracy of the V4 option is ± 0.1%.

1.3.2 Option V5

The V5 option provides the same gain steps and vernier multiplier as the V4 option. However, the gain accuracy of the V5 option is ± 0.01% after a 4 hour warm-up time.

1.4 SPECIFICATIONS

Specifications are listed in Table 1.1.

1.5 AMPLIFIER ENCLOSURES

The 2808 Enclosure accommodates eight amplifiers. The enclosure is 7 inches in height with a depth of 22 inches and a width, including flanges, of 19 inches.

Table 1.1 - Specifications

DANA MODEL 2860 SPECIFICATIONS	All specifications apply for 0 to 1000 ohm source, in any unbalance.
Gain	
Range	1 to 2500 with 2.5:1 vernier
Steps	1, 2, 5, 10, 20, 50, 100, 200, 500, 1000
Accuracy	±0.01% V5 option; ±0.1% V4 option
Resolution	±0.01% (±0.03% worst case)
Stability (at gain setting and constant temperature)	±0.01% (200 hrs)
Temperature coefficient	±0.005%/°C
Output (no damage for sustained short circuit)	
Full scale voltage	±10 V
Voltage overrange, nominal	20%
Full scale load current	±100 mA
Maximum short circuit current	±150 mA (adjustable to ±60 mA)
Impedance	0.1 ohm in series with 30μH
Capacitive load, without instability	Infinite
Capability	Full scale voltage and current to 50 kHz
Frequency Response (at full output)	
Wideband	
dc to 100 Hz	±0.01%
Minimum 3 dB frequency	50 kHz
Variband	
Filter characteristics	3 pole Bessel
Switch selectable cutoff frequencies (f_{co}) of	10 Hz, 100 Hz, 1 kHz, 10 kHz, wideband
Attenuation at selected f_{co}	−3 dB ±1 dB
Attenuation above selected f_{co}	−60 dB/decade
Linearity	
dc to 2 kHz	±0.01%
Common Mode	
Rejection ratio at dc	140 dB
Rejection ratio dc to 60 Hz	120 dB
Operating voltage dc to 60 Hz	300 V dc or peak ac
Fault voltage dc to 60 Hz without damage	300 V dc or peak ac
Noise	
Full bandwidth	3μV rms RTI + 2 mV rms RTO
10 kHz bandwidth	1μV rms RTI + 1 mV rms RTO
10 Hz bandwidth	1 mV peak to peak RTO, for any gain
Input Impedance	
Normal mode	10,000 MΩ, parallel with 0.001 μF
Zero Stability	
At constant temperature (after 30 minute warm-up)	±0.02% (200 hrs)
Temperature coefficient	(±0.002% RTO ±1 μV RTI)/°C and ±0.5 nA RTI/°C
Step Function Response	
Settles to final value ±0.01% of full scale in	$175\ \mu\text{sec} + \frac{1.6\ \text{sec}}{f_{co}}$
Overload Recovery	
Settles to final value ±0.01% of full scale for 5 times full scale input for gains of 5 to 2500 or 10 V for gains of 1 to 5 in	$400\ \mu\text{sec} + \frac{1.6\ \text{sec}}{f_{co}}$
No damage for 30 V dc or peak ac input on any gain	
Temperature Range	
Operating	0°C to +50°C
Storage	−20°C to +75°C
Power Requirement	
Domestic	105 to 125 V rms, 50 to 400 Hz, 10 watts
Export Option 1	200 to 240 V rms, 50 to 400 Hz, 10 watts
Export Option 2	215 to 265 V rms, 50 to 400 Hz, 10 watts
Export Option 3	90 to 110 V rms, 50 to 400 Hz, 10 watts
Enclosure	
Model	2808-1 or 2808-2
Capacity	8 amplifiers fit in a standard 7 inch by 19 inch panel space
Bench Operation	
Model	2801 single unit adapter

The basic model is modified by a "dash" number which specifies the type of wiring.

The 2808 Enclosure accommodates all of the Dana Series 2800 Amplifiers. The amplifiers are interchangeable in the enclosure without alteration of the input and output cables.

The -1 Enclosure contains connectors to accommodate system wiring. Fusing and AC wiring are factory wired. An outline drawing (452402) is included in Section 6, "Drawings and Parts Lists".

The -2 Enclosure is fully wired. The inputs and outputs are accessible through connectors mounted on the rear panel. An outline drawing (452403) is included in Section 6, "Drawings and Parts Lists".

The model 2802-2 Enclosure accommodates two 2800 series amplifiers. All 2800 series amplifiers are interchangeable in the enclosure without alteration of the input and output cables.

The 2802-2 can be adapted for bench use or for rack mount use. Dimensions of the enclosure are, height 3.5 inches, depth 20 inches, width 17 inches. Inputs and outputs are accessible through connectors mounted on the rear panel. An outline drawing (402948 page 1 of 3) is included in Section 7, "Drawings and Parts Lists".

Wiring instructions for each type enclosure are included in Section 2, "Installation".

1.6 AMPLIFIER ACCESSORIES

An Adapter Set Model 2801 (Dana part number 402468) and an Amplifier Support Bracket (Dana part number 452411) are used when the amplifier is operated on the bench. The Adapter Set (item 1 in Figure 1.3) contains input leads, output leads, and the power cord. The Amplifier Support Bracket (item 2 in Figure 1.3) mounts to the amplifier to support the amplifier in an upright position.

Figure 1.3 - Amplifier Accessories

SECTION 2

INSTALLATION AND INITIAL CHECKOUT

2.1 UNPACKING AND INSPECTION

The Dana Amplifier is shipped in a special reusable shipping package, designed to protect the instrument from excessive shock and vibration. Examine the package for signs of external damage before removing the unit. If external damage is present, notify the carrier before proceeding. Next, examine the outside of the amplifier for any evidence of damage due to excessive shock, vibration, water leakage, etc.

If the unit appears in perfect condition, proceed with the installation. However, if there is any apparent damage, communicate with the carrier for instructions.

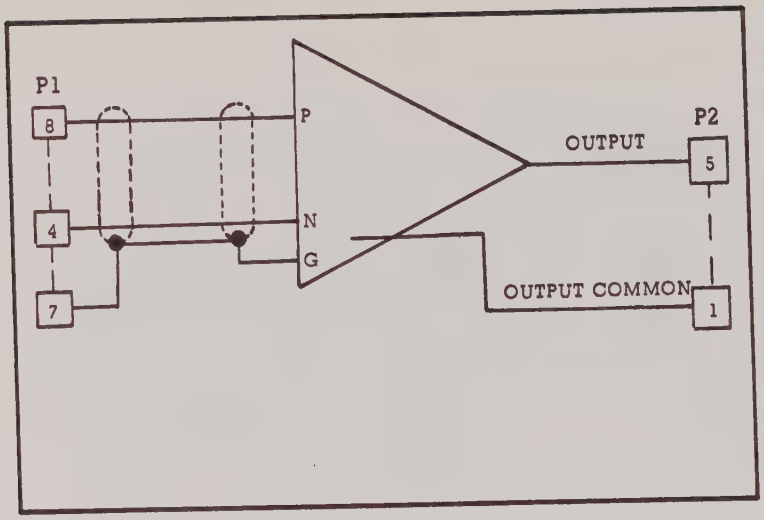
2.2 POWER REQUIREMENTS

Dana Amplifiers, manufactured for domestic use, operate on 115 volts (±10 volts), 50 to 400 Hz. Units manufactured for export operate on 210 to 250 volts, 50 to 400 Hz. Power required is eight watts.

> NOTE
>
> If the Amplifier has been stored for a prolonged period (5 or 6 months) without use, it is recommended that it be operated with a variable transformer, such as a Variac, at one-half line voltage for about two hours before gradually applying full power. This is done to "reform" the electrolytic capacitors in the amplifier and reduce the chance of capacitor failure.

2.3 INPUT - OUTPUT CONNECTIONS

Input and output connections to the amplifier are through an eight pin connector (P1 and P2) at the rear of the amplifier (see Figure 2.1). External connections are brought in through a mating connector. When the Dana enclosures are used, the mating connector for each amplifier is mounted on the inside back panel of the enclosure; each amplifier plugs into its corresponding connectors. When amplifiers are used singly, a single unit adapter set is normally used. The adapter set (Dana part number 402468) includes the mating connector, power cord, and clip leads for input and output signal connections.



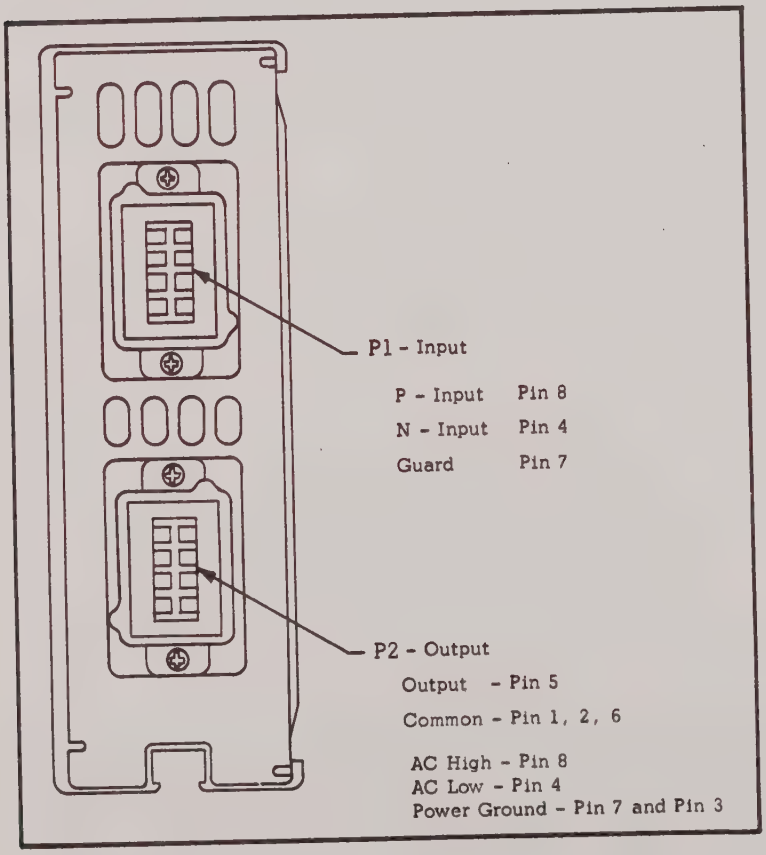

P1 - Input
P - Input Pin 8
N - Input Pin 4
Guard Pin 7
P2 - Output
Output - Pin 5
Common - Pin 1, 2, 6
AC High - Pin 8
AC Low - Pin 4
Power Ground - Pin 7 and Pin 3

Figure 2.1 - Input/Output Connections

When the 2808-1 Enclosure is used, external connections are made directly to the solder side of the enclosure mounted connector for each amplifier. Access to connectors is gained by removing four screws holding the rear panel and allowing the top of the rear panel to drop away from the enclosure. External leads are routed through the grommet holes and soldered to the connectors.

In the 2808-2 Enclosure, conventional cable connectors are mounted on the rear panel. Connections are made by wiring to the mating connector. All pin connections are identified in Figure 2.2.

2.3.2 Power

When the Amplifier is to be operated within the 2808-1 or 2808-2 Enclosure, power is prewired and a three-wire line cord is supplied. When using the cord set, power and input/output connections are prewired. The power cord is connected to J2 of the cord set.

The ground wire of the power cord connects to the internal power supply shield of the amplifiers.

2.3.3 Input/Output Signals

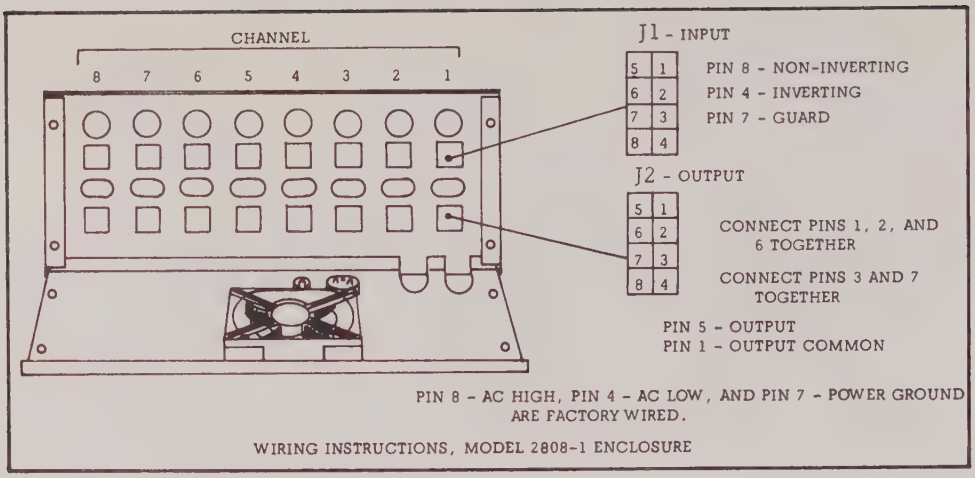
Input wiring configurations are extremely important in minimizing common mode voltages. The guard lead should be connected as close as possible to the signal source. Input and output connections are shown in Figure 2.2.

For permanent installations, low thermal solder (70% cadmium, 30% tin) should be used for all input connections to reduce thermalcouple errors. For temporary or test setups, screw terminals or clips having low resistance may be used, taking suitable care to minimize thermal emf's (a few microvolts can be significant on high gain ranges.

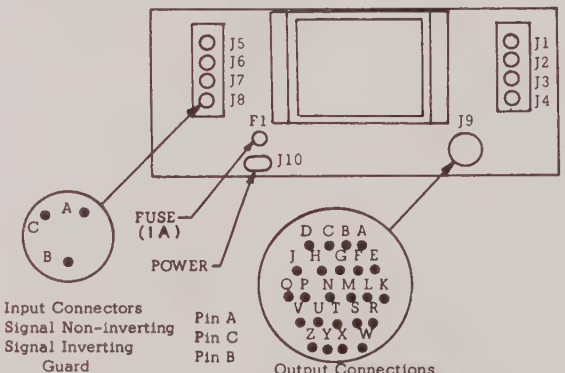
Since P and N inputs to the amplifier are symmetrical (approximately equal impedance to output common), either lead may be connected to either side of the signal source. For phasing purposes, if P is positive with respect to N, the output is positive with respect to output common.

Input leads should be two-conductor in an insulated shielded cable (Belden #8451-500, or equivalent). The shield must be soldered to the guard pin connection (pin 7 of P1 when a -1 Enclosure is used; pin B of the signal input connector for a -2 Enclosure). The unshielded portion of the leads must be kept as short as possible.

A single-conductor shielded cable is recommended for output leads. If two-conductor is used, connect one lead and shield together at either end or both ends. Solder the shield to Output Common (pin 1 of P2 for -1 enclosures; see Figure 2.1 for -2 enclosures). The enclosure chassis is connected to ground by the power cable. The lead from the output common terminal of the amplifier should be connected directly to the input common or ground of the output device.


CHANNEL
8 7 6 5 4 3 2 1
J1 - INPUT
5 1
6 2
7 3
8 4
PIN 8 - NON-INVERTING
PIN 4 - INVERTING
PIN 7 - GUARD
J2 - OUTPUT
5 1
6 2
7 3
8 4
CONNECT PINS 1, 2, AND 6 TOGETHER
CONNECT PINS 3 AND 7 TOGETHER
PIN 5 - OUTPUT
PIN 1 - OUTPUT COMMON
PIN 8 - AC HIGH, PIN 4 - AC LOW, AND PIN 7 - POWER GROUND ARE FACTORY WIRED.

WIRING INSTRUCTIONS, MODEL 2808-1 ENCLOSURE



Output Connections

CHANNEL	OUTPUT	OUTPUT COMMON
1	A	B
2	E	F
3	K	L
4	R	S
5	W	X
6	D	C
7	J	H
8	Q	P

CHASSIS GROUND PIN Z

NOTES: (1) Use shielded two conductor twisted pair cable for input leads. Shield is soldered to Guard Pin Connection.

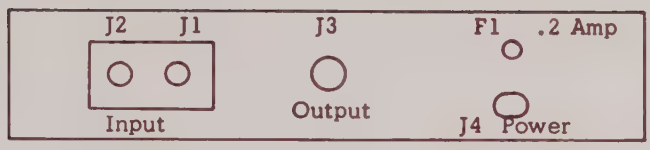
(2) Single conductor shielded wire is recommended for output leads. Solder shield to output common pin.

(3) Viewing enclosure from the front, amplifiers are numbered from left to right.

	Mating Connector & Clamps	Dana Part Number
INPUT	3106 A-10 SL-3S A105-A115	601561
(8 sets required)	3057-4A-A105 w/Bush	601474
OUTPUT	3106 A-24-28P-639	601563
(1 set required)	3057-16A-639 w/Bush	601564
AC POWER	Belden Power Cord #17256	600127
(1 set required)		

Wiring Instructions, Model 2808-2 Enclosure

Figure 2.2 - Enclosure Wiring



Input Connectors

Pin A	Signal Non-Inverting
Pin B	Guard
Pin C	Signal Inverting

Output Connector

Pin A	Channel 2 Output
Pin C	Output Common Channel 2
Pin D	Connector Shell
Pin E	Output Common Channel 1
Pin G	Channel 1 Output

Figure 2-3 2802-2 Enclosure Wiring

2.4 INITIAL CHECKOUT PROCEDURES

The amplifier is accurately adjusted and carefully inspected at the factory. The following tests check basic characteristics of the amplifier to verify proper operation upon delivery. The type of damage that can be expected in shipment tends to produce gross malfunctions rather than minor changes in sensitive characteristics. More complete and precise tests and calibration procedures are included in Section 5, "Calibration".

Only three items of test equipment are required to perform initial checkout of the amplifier:

- Audio Oscillator
- Voltage Divider/Attenuator
- Oscilloscope

Standard laboratory-type instruments from any manufacturer may be used.

2.4.1 Gain Checkout

1. Connect the common or ground terminals of each item of test equipment to a single point and to the amplifier output common (pin 1 of P2). Connect this point to ground. Make all measurements relative to this point (see Figure 2.4).

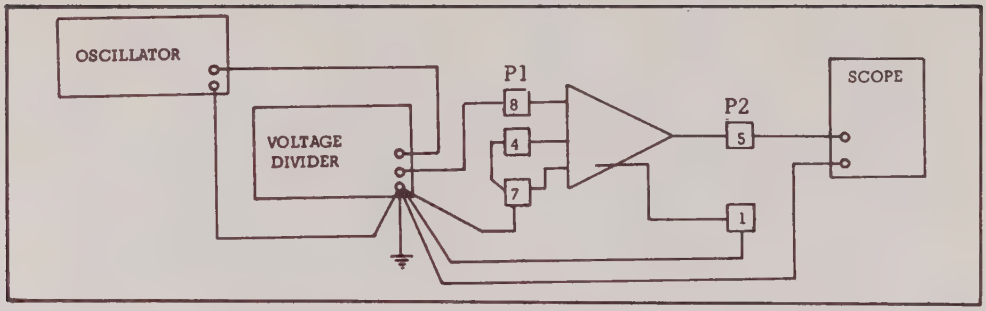


Figure 2.4 - Gain Test Setup.

2. Set voltage divider to minimum output — zero, if possible.

3. Apply power to amplifier. Observe amplifier output on oscilloscope. It should be within a few millivolts of ground and change only very slightly as the amplifier GAIN switch is rotated.

4. Set the VERNIER gain adjustment fully counterclockwise.

5. Set the GAIN selector switch at the highest gain position. If the amplifier is equipped with a Gain Multiplier switch (V2), set it to X 1.0.

6. Remove scope lead from amplifier output and connect scope to the oscillator output. Adjust oscillator for 20 volts, peak-to-peak, at 100 Hz.

7. Set voltage divider to the reciprocal of the maximum gain setting, 1/K. (For example, at maximum gain of 1000, set divider to 0.001.)

8. Return the scope to the amplifier output, pin 5 of P2. The scope should now indicate approximately the same value, 20 volts peak-to-peak, observed at the oscillator output. (The term "approximately" is used because of the limited capability of an oscilloscope to compare two magnitudes accurately.)

9. Verify that there is no obvious noise or other unexplained distortions on the oscilloscope trace.

2.4.2 Frequency Response Checkout

1. Use test setup exactly as connected for Gain checkout. Set amplifier GAIN control at maximum; vernier adjustment to minimum. Connect scope to oscillator output; set oscillator frequency to 50 kHz. Set the BANDWIDTH switch to the WB (wideband) position.

2. Set oscillator output at 20 volts, peak-to-peak (on scope).

3. Remove scope lead from oscillator and connect to amplifier output pin 5 of P2. Adjust voltage divider for amplifier output amplitude equal to that observed in step 2.

4. Compare voltage divider setting with zero - or minimum output position. The difference should be no less than 3 dB, or approximately 30%.

2.4.3 Common Mode Rejection

1. Short the amplifier input leads and the input guard lead (pins 8, 4, and 7 of P1). Connect these leads to the high side of a signal generator.

2. Connect oscilloscope to amplifier output (pin 5 of P2).

3. Set oscillator output to 20 volts, peak-to-peak, at 60 Hz.

4. Set amplifier GAIN switch to 1000.

5. Observe amplifier output on scope. The output due to common mode is normally not detectable above the wideband noise of the amplifier. Common mode rejection can be calculated as follows:

$$CMR = \frac{20 \text{ Volts (P-P)} \times K}{\text{Output Voltage (P-P)}}$$

SECTION 3

OPERATION

3.1 CONTROLS

3.1.1 Gain Selector Switch

The GAIN switch is rotated to select the desired gain of the amplifier. One of ten gain positions may be selected. The selected gain is inscribed on the knob of the gain selector switch.

3.1.2 Bandwidth Switch

The BANDWIDTH switch allows selection of the amplifier bandwidth. It is calibrated in kilohertz and has the following positions:

Switch Position	Bandwidth
0.01	DC to 10Hz
0.1	DC to 100Hz
1.0	DC to 1000Hz
10.0	DC to 10kHz
Wideband (WB)	Full Bandwidth

3.2 OPERATIONAL ADJUSTMENTS

3.2.1 ZERO Adjustment

ZERO is a screwdriver adjustment on the front panel of the amplifier. It is used to set the output voltage to zero volts with no input. It is adjusted in the following manner:

1. Apply power to the amplifier and any adjoining heat-producing equipment and allow amplifier to stabilize (approximately 30 minutes).
2. Set GAIN selector switch to lowest gain position.
3. Return the input P(P1-8) and N(P1-4) leads to output common (P2-1).
4. Connect voltmeter or scope to amplifier output (P2-5) and common (P2-1).

Model 2860

5. Adjust ZERO for zero amplifier output. Counterclockwise rotation corrects for a positive output; clockwise rotation corrects for a negative output.

3.2.2 GAIN Adjustment

This is a screwdriver adjustment which serves as a vernier adjustment of gain selected by the GAIN selector switch. The adjustment varies each gain position by a factor of 2.5:1 — providing continuous gain selection throughout all available ranges.

3.3 OPERATING PROCEDURES

After installation of the amplifier as described in Section 2, operation consists simply of selecting the appropriate gain. The amplifier is ready for use immediately with zero stability achieved within 30 minutes.

SECTION 4

CIRCUIT DESCRIPTION

4.1 INTRODUCTION

A block diagram of the Model 2860 amplifier is shown in Figure 4.1. The forward loop consists of the preamplifier, isolator, and output amplifier. The preamplifier amplifies the potential difference between the two inputs e_1, e_2. The output of the amplifier is proportional to the difference of the amplitudes. These signals are referred to as "normal mode signal" (also referred to as "difference" or differential signals). The potentials common to both inputs are referred to as "common mode potentials" and are physically isolated from the preamplifier by a mechanical enclosure.

The normal mode signals are defined as

$$\text{Normal Mode Signal} = e_2 - e_1$$

$$\text{Output } (E_o) = (e_2 - e_1) \text{ (Gain)}$$

In single ended operation, a signal is applied to e_2 while e_1 is common; therefore, the output is proportional to the amplitude of the one signal applied.

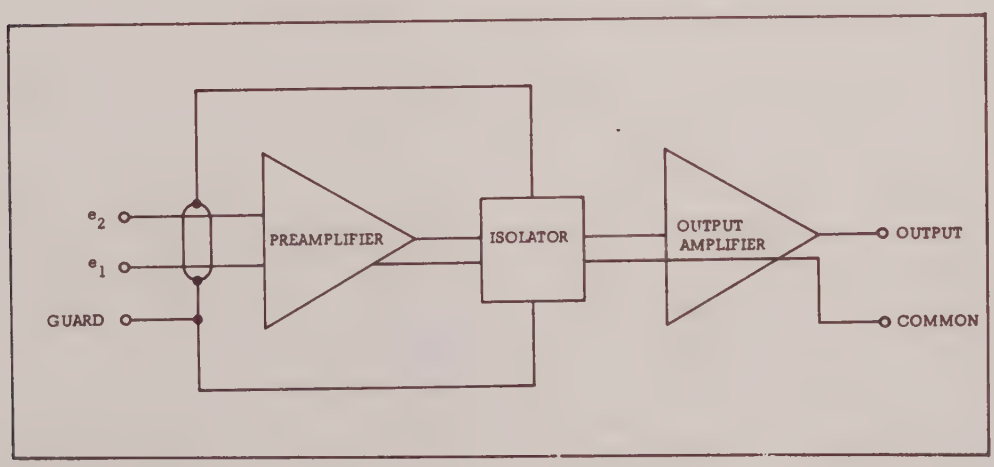


Figure 4.1 - Block Diagram, Model 2860 Amplifier

4.2 PREAMPLIFIER

The Preamplifier is shown in Figure 4.2. The normal mode signals are converted into current and applied to the isolator. The gain resistor (R_G) scales the input voltage such that the full scale current (i) to the isolator is 1 milliampere for all possible full scale input signals (10 millivolts to 10 volts). The required resistor R_G is switched into the circuit by the GAIN switch on the front panel. Values of R_G range from 10 ohms to 10,000 ohms according to the relation

$$R_G = \frac{e_2 - e_1}{1 \text{ milliampere}}$$

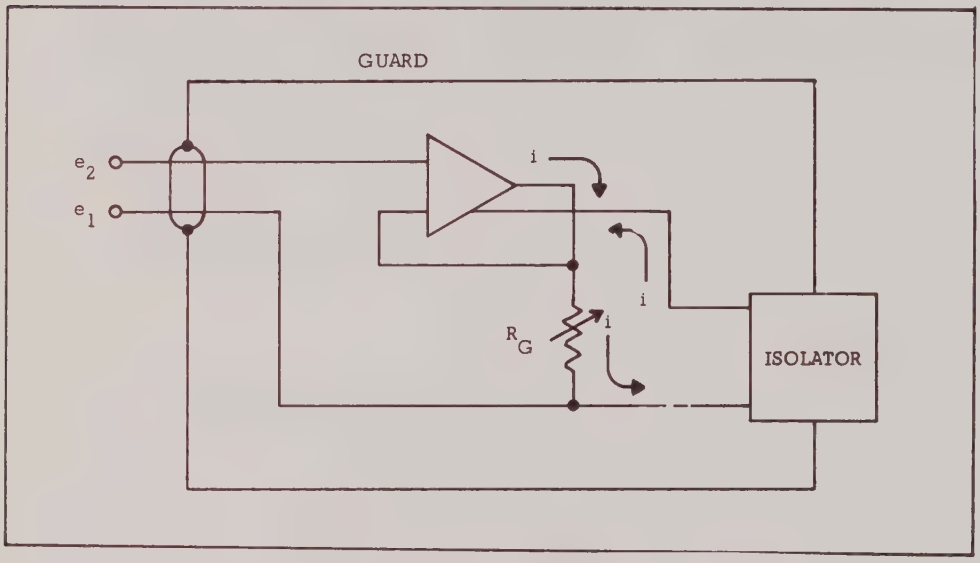


Figure 4.2 - Preamplifier

4.3 ISOLATOR

The Isolator contains a transformer, a modulator, and a demodulator as shown in Figure 4.3. The current enters the primary winding of the transformer from the preamplifier, is modulated, and coupled to the secondary winding of the transformer where it is demodulated in the demodulator section of the isolator. The modulator and demodulator are synchronized from the same source for the proper phasing of the signal. An astable multivibrator provides the switching source to the modulator switches and the demodulator switches as shown in Figure 4.4.

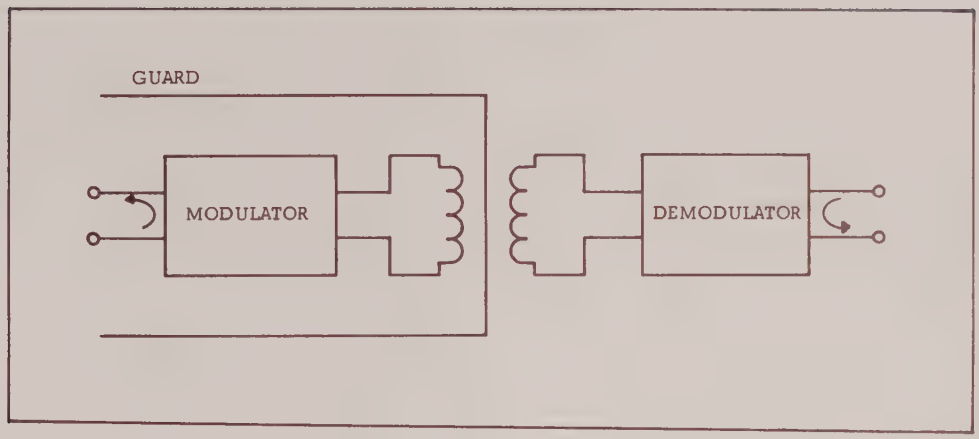


Figure 4.3 - Isolator

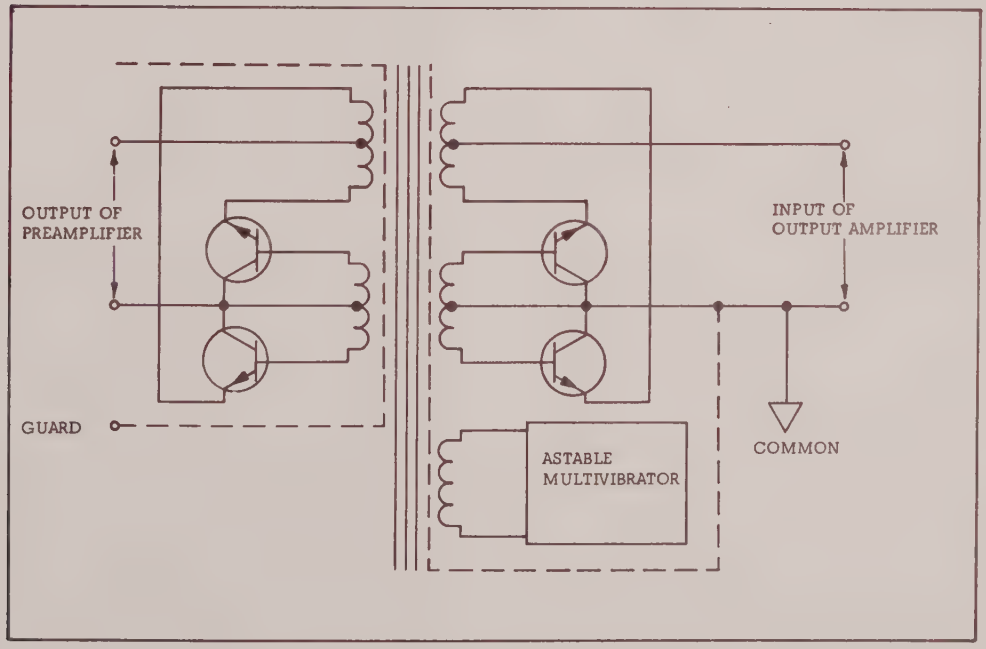


Figure 4.4 - Modulator and Demodulator

4.4 OUTPUT AMPLIFIER

The Output Amplifier (Figure 4.5) consists of an operational amplifier, active-admittance filter, and buffer amplifier. A negative feedback trim potentiometer is the vernier gain adjust for the amplifier. Current at the input is converted to voltage at the output. The active-admittance filter is a three pole Bessel filter consisting of a resistor R_1 and an active filter (Y) that attenuates the signal 3dB at the selected cutoff frequency (front panel BANDWIDTH control). Attenuation above the cutoff frequency is 18dB per octave, 60dB per decade. The buffer amplifier is a unity gain amplifier that provides $\pm$100 milliamperes to a load of 100 ohms.

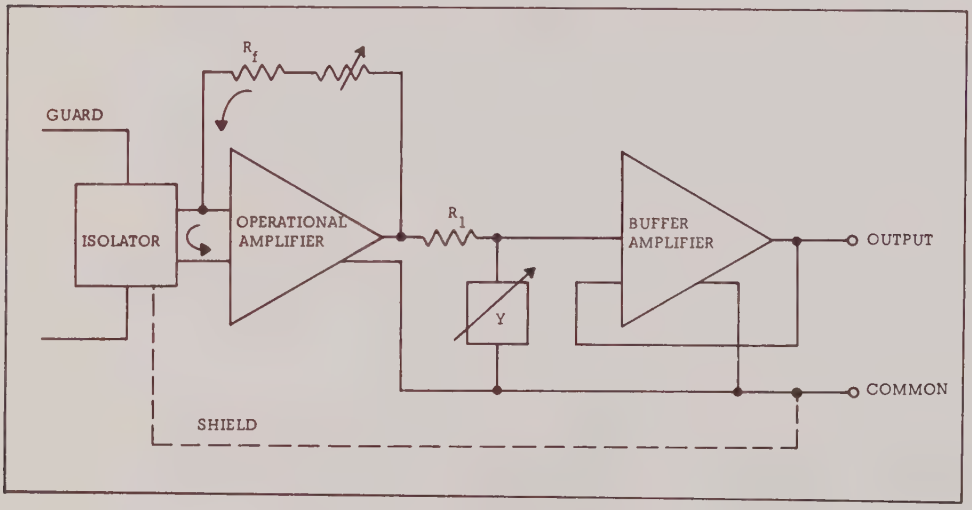


Figure 4.5 - Output Amplifier

SECTION 5

CALIBRATION

5.1 TEST EQUIPMENT

1. OSCILLOSCOPE - X-Y inputs; bandpass, DC - 500 kHz; calibrated deflection factors of 1 millivolt to 20 volts per centimeter accurate within 3%; input impedance, 1 megohm paralleled by less than 50 pf.
2. OSCILLATOR - Frequency range, 5 Hz - 500 kHz; accuracy, ± 2%; frequency response, ± 1 dB; adjustable output voltage, 160 milliwatts (10 volts) into 600 ohms rated load, 20 volts open circuit.
3. VACUUM TUBE VOLTMETER - Voltage range, 0.1 millivolt to 300 volts; dB range, -72 to +52 dB; frequency range, 10 Hz to 1 MHz accurate within ± 2% (50 Hz - 500 kHz); input impedance, 10 megohms paralleled by less than 50 pf.
4. ATTENUATOR - Attenuation to 120 dB in 1 dB steps; DC to 1 MHz accurate within ± dB; power capacity, 5 watts.
5. DC MILLIVOLTMETER (Optional)
6. Dana Adapter Set 2801 (P/N 402468).

5.2 CALIBRATION PROCEDURES

Certain performance characteristics should be checked periodically and internal adjustments made as required. These adjustments are detailed in paragraph 5.3 - Field Calibration.

The calibration procedure in paragraph 5.4, Major Calibration, should be performed after repair of the instrument.

5.3 FIELD CALIBRATION

Physical location of the adjustable components is shown in Figure 5.1. The procedure below should be performed in the order listed.

> NOTE: Common mode potentials appear between the guard box and chassis; therefore, an insulated screwdriver or adjustment tool (J.F.D. Adjustment Tool 5284) should be used to make the adjustments.

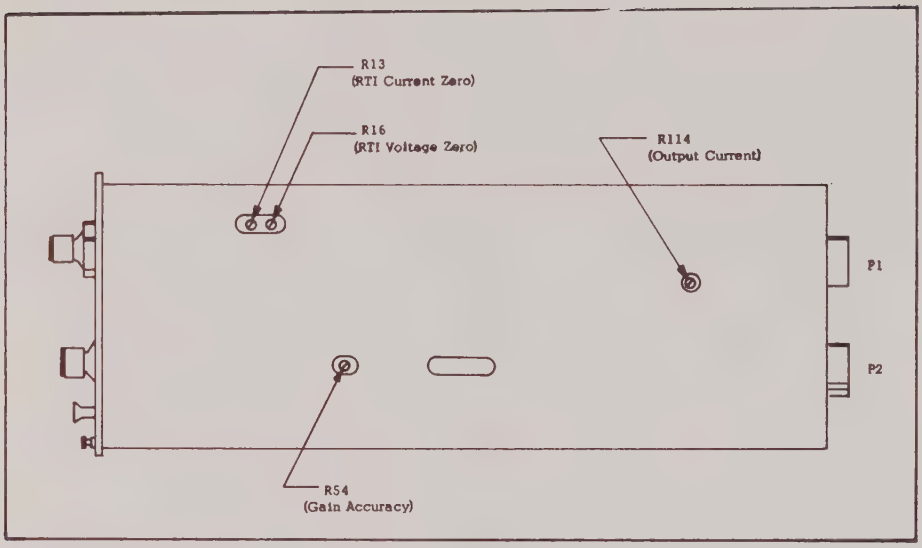


Figure 5.1 - Amplifier Adjustments, Physical Location

5.3.1 Referred to Input (RTI) Voltage Zero

In addition to the operational ZERO adjustment on the front panel, the amplifier is equipped with an internal zero adjustment (R16). Procedure for making the adjustment is as follows:

1. Connect amplifier inputs P(P1-8), N(P1-4), and guard (P1-7) together.

2. Connect an oscilloscope or millivoltmeter to output (P2-5) and common (P2-1).

3. Set the front panel GAIN vernier (R55) fully counterclockwise.

4. Set the GAIN switch to the gain of 1; adjust the front panel ZERO adjustment (R60) for minimum reading on the millivoltmeter. Record any residual offset.

5. Set the amplifier GAIN switch to the gain of 1000; adjust the internal collector zero adjustment (R16) for the same offset recorded in step 4.

6. Repeat steps 4 and 5 until the output remains the same on both the highest and lowest gain settings.

5.3.2 Referred to Input (RTI) Current Zero

This adjustment minimizes current flow through the input terminals. For most accurate adjustment, the following procedure should be performed after the RTI Voltage zero adjustment.

1. Set amplifier GAIN switch to the gain of 1000.
2. Connect input terminals P(P1-8), N(P1-4), and guard (P1-7) together.
3. Set the front panel GAIN vernier (R55) fully counterclockwise.
4. Connect oscilloscope to output (P2-5) and common (P2-1). Set vertical deflection to 1mV/cm. Record amplitude of offset voltage at output.
5. Disconnect P(P1-8) terminal from N(P1-4) and guard (P1-7), insert 1K resistor in series and reconnect to N(P1-4) and guard (P1-7).
6. Adjust R13, the base current zero control, for the same offset recorded in step 4.

5.3.3 Gain Accuracy Adjustment

The gain trim adjustment sets the gain accuracy of the amplifier. The gain accuracy for the V4 option is ± 0.1%, the gain accuracy for the V5 option is ± 0.01%.

1. Connect the test setup shown in Figure 5.2.

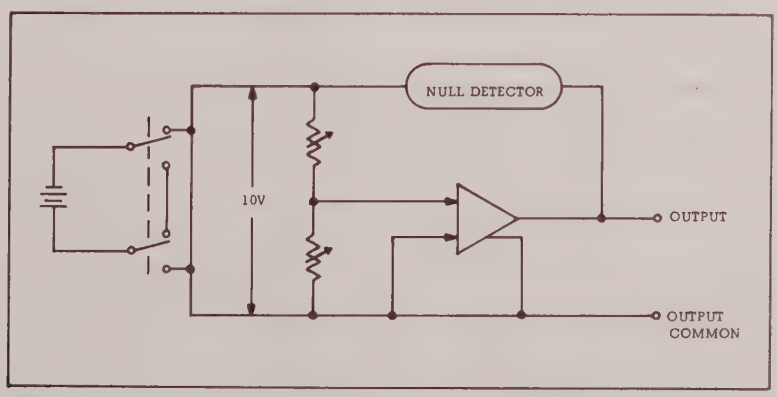


Figure 5.2 - Gain Accuracy Adjustment

2. Set the vernier gain adjustment on the front panel of the amplifier fully counterclockwise.
3. Set the GAIN selector switch of the amplifier to the gain of 100.

4. Set voltage divider* to the reciprocal of gain setting, 1/k. (For the gain of 100, set the voltage divider to 0.01).

5. Adjust the gain trim (R54) for null. For V4 option, adjust for ± 10 millivolts; for V5 option, adjust for ± 1 millivolt.

5.3.4 Current Limit Adjustment

Potentiometer R114 adjusts the output current. The current should be limited to protect the recording device; however, the current can be limited to 100 milliamperes into a 10 ohm load.

1. Connect a 10 volt power supply, a 10 ohm 1/2 watt load resistor, and a DC voltmeter as shown in Figure 5.3.

2. Adjust R114 until the voltmeter reads 1.0 volts ± 10%.

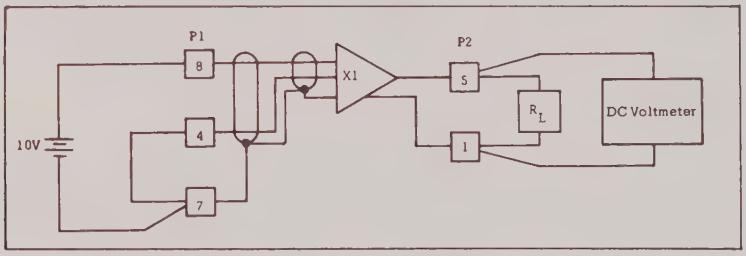


Figure 5.3 - Test Setup, Current Limit Adjust

5.3.5 Gain Linearity Check

Linearity is the deviation from the best straight line output, not necessarily through zero. Linearity is specified at ± 0.1% for the V4 option and ± 0.01% for the V5 option. As tested below with a 20 volt peak-to-peak full scale output, ± .01% linearity requires that the output be within ± 2 mV of the best straight line output.

1. Perform steps 1 through 4 of the Gain Accuracy procedure (5.3.3).

2. Measure the null deviation as the voltage source is varied between +10 volts and -10 volts.

3. The maximum peak-to-peak error over the ± 10 volt signal must be no greater than 4 mV for the V5 option or 40 mV for the V4 option.

---

*The gain accuracy of the amplifier can be no greater than the accuracy of the voltage divider used.

5.4 MAJOR CALIBRATION

Disassemble the amplifier per paragraph 5.5.

5.4.1 Output Amplifier Zero Adjustment

Potentiometer R67 (reference assembly drawing 402944) adjusts the zero of the output amplifier.

1. Apply power to the amplifier and allow 30 minutes for warm-up.
2. Connect terminal E60 (reference assembly drawing 402944) to output common (pin 1 of connector P2).
3. Connect an oscilloscope or millivoltmeter to output (pin 5 of connector P2) and output common (pin 1 of connector P2).
4. Set the front panel GAIN vernier (R55) full counterclockwise.
5. Adjust potentiometer R67 (reference assembly drawing 402944) for $\pm$ 5 volts.
6. Remove the common connection from terminal E60; connect terminal E61 to common.
7. Adjust potentiometer R52 (reference assembly drawing 402944) for zero volts $\pm$ 200 microvolts.
8. Remove the common connection to terminal E61.

5.4.2 Referenced to Output (RTO) Zero Adjustment

1. Connect the P(P1-8), N(P1-4), and guard (P1-7) leads together.
2. Place the GAIN switch to the gain of 1.
3. Connect a millivoltmeter to output (P2-5) and output common (P2-1).
4. Set the front panel GAIN vernier (R55) fully counterclockwise.
5. Set the front panel ZERO (R60) for zero volts $\pm$ 500 microvolts; record this voltage for further reference.
6. Set the front panel GAIN vernier (R55) fully clockwise; adjust potentiometer R52 (reference assembly drawing 402944) for the same value recorded in step 5.

7. Set the front panel GAIN vernier (R55) fully counterclockwise. The offset voltage should be the same as the voltage recorded in step 5.

8. Repeat steps 4 through 7 until the offset voltage remains the same.

5.4.3 Referred to Input (RTI) Voltage Zero Adjustments

Perform the calibration procedure in paragraph 5.3.1.

5.4.4 Referred to Input (RTI) Current Zero Adjustment

Perform the calibration procedure in paragraph 5.3.2.

5.4.5 Gain Accuracy Adjustment

Perform the calibration procedure in paragraph 5.3.3.

5.4.6 Current Limit Adjustment

Perform the calibration procedure in paragraph 5.3.4.

5.5 AMPLIFIER DISASSEMBLY

Remove eight, number 6, Phillips flat-head screws from the aluminum support (right-hand side of the amplifier as viewed from the front panel.)

To remove the cover, place the amplifier in the left hand and pull the cover toward the rear of the amplifier as shown in Figure 5.4a.

To remove the aluminum support, remove six, number 4, Phillips pan-head screws holding the circuit board assembly to the aluminum support. Three screws are at the top of the circuit board assembly; the other three screws are at the bottom of the circuit board assembly. Place the amplifier in the left hand and push the circuit board assembly as shown in Figure 5.4b.

Figure 5.4a

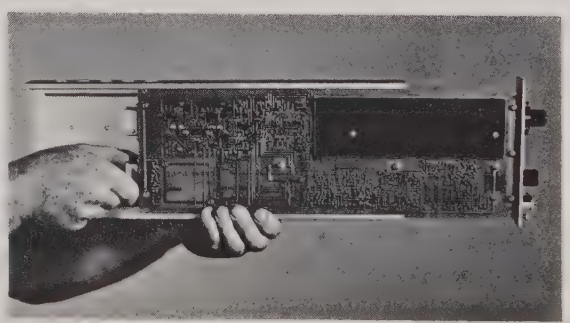


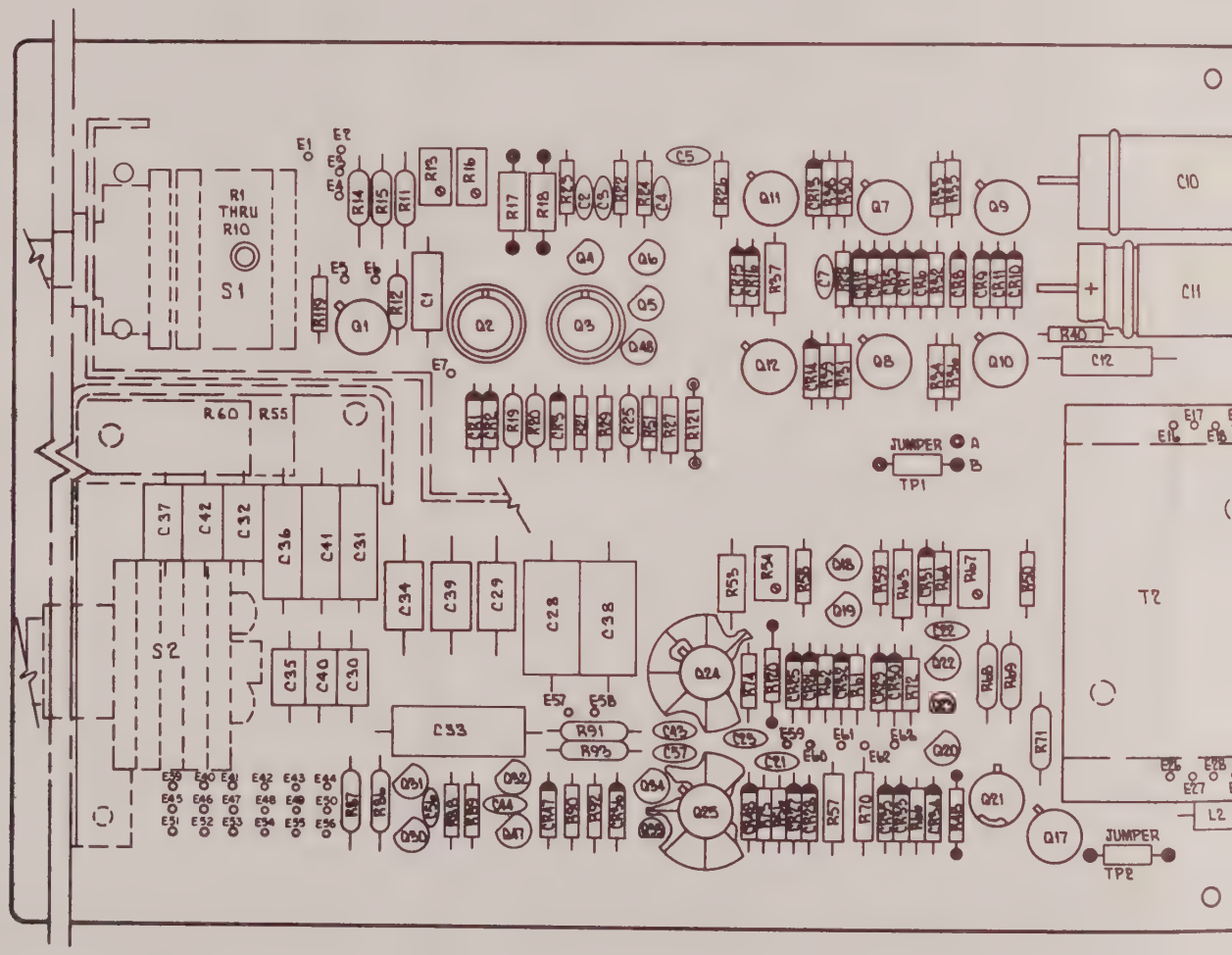
Figure 5.4b

SECTION 6

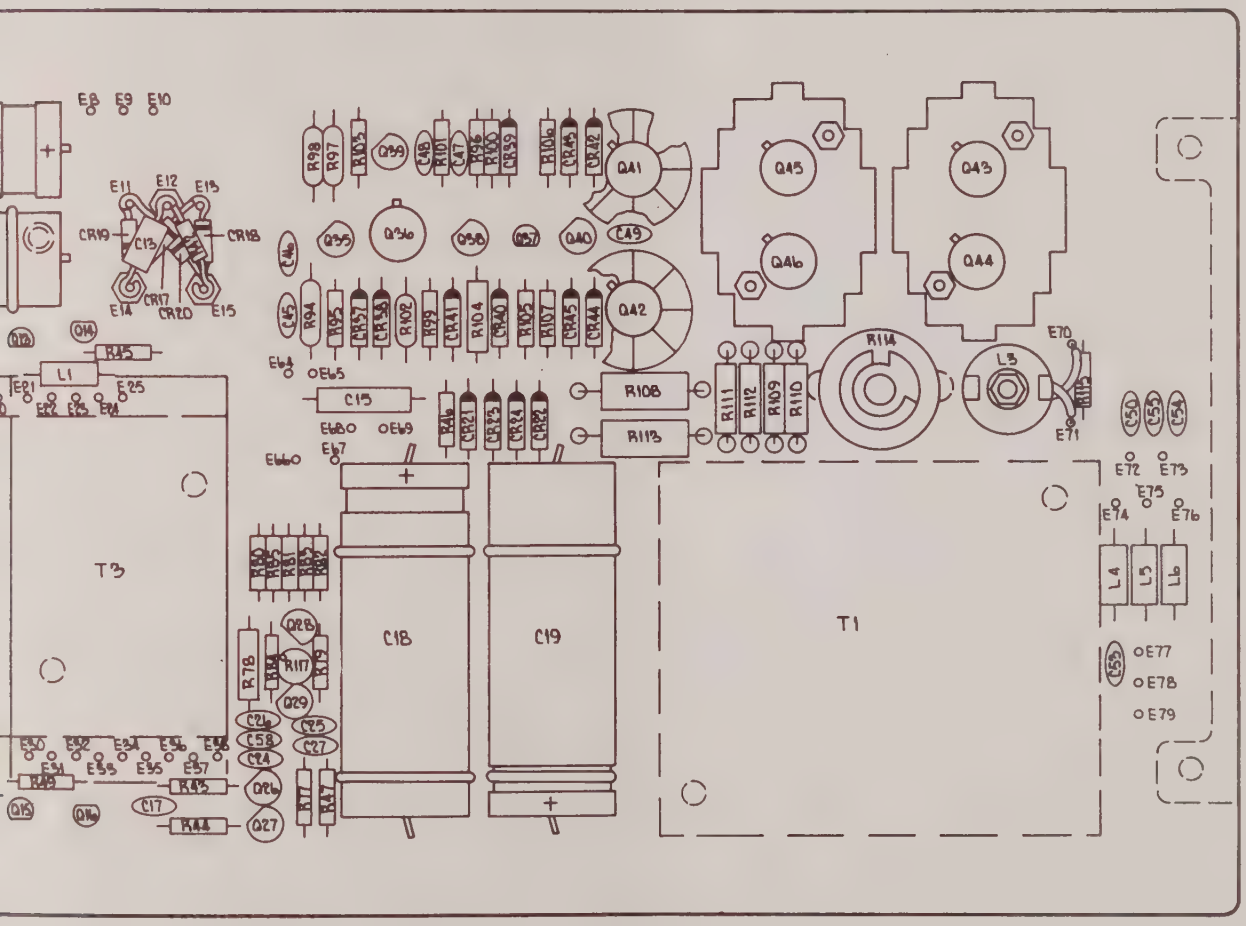
DRAWINGS AND PARTS LIST

6.1 DRAWINGS

PCB Assembly - Model 2860 V4 & V5	402944
Schematic - Post Isolator 2860 V4 & V5	430785
Dimensional Outline - 2860	452648
Dimensional Outline - 2808-1	452402
Wiring Diagram - Enclosure Model 2808-1	430590
Dimensional Outline - 2808-2	452403
Wiring Diagram - Enclosure Model 2808-2	430591
Assembly - 2802-2	402948



NOTES: UNLESS OTHERWISE SPECIFIED

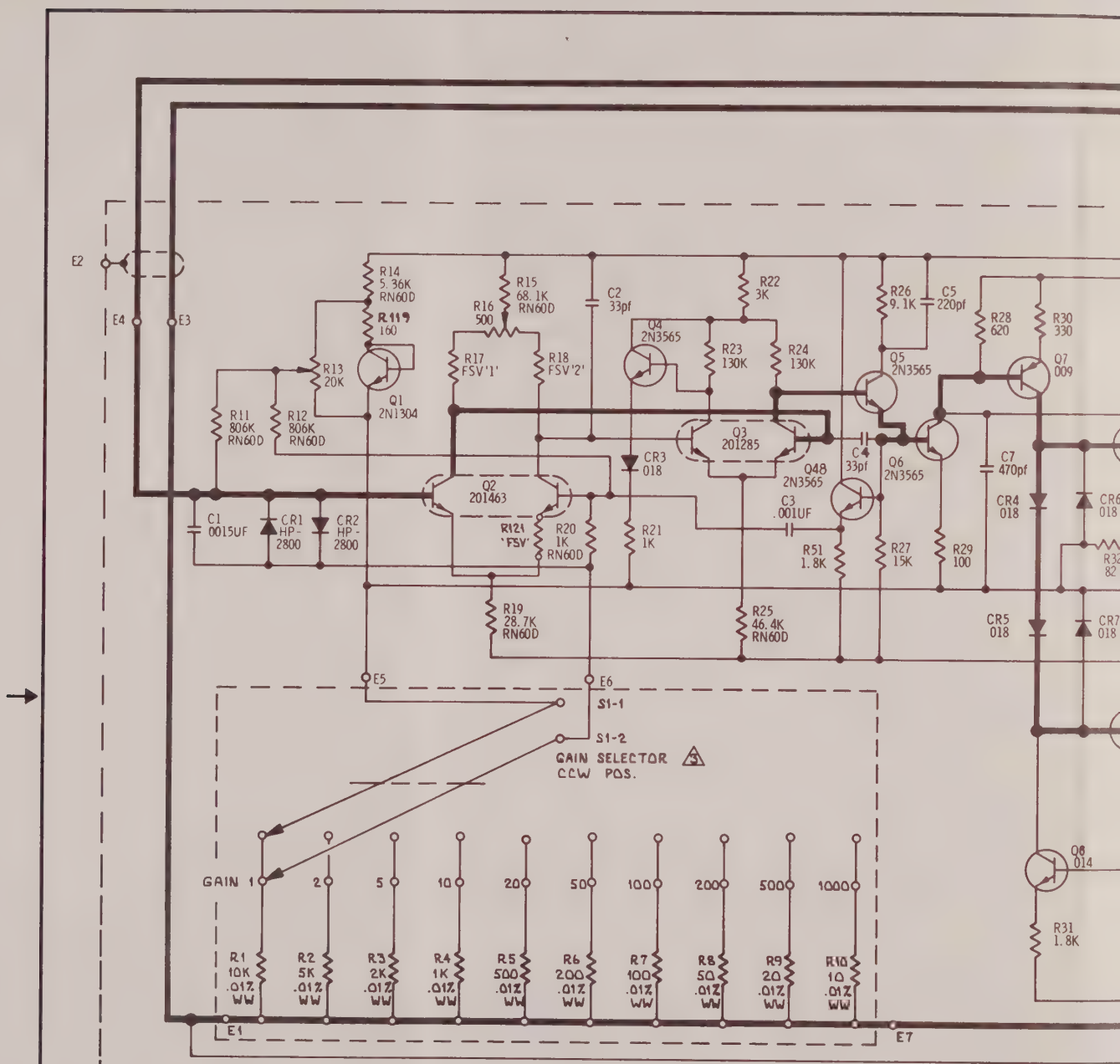


DANA LABORATORIES INC.
IRVINE, CALIFORNIA

PC BOARD ASSY—MODEL 2860 V5

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	402944	V

SCALE 2:1 SHEET 1 OF 1



6. CONN. SHELL TIED TO GUARD AT PIN 2 OF P1.

5. 'E1 NUMBERS DENOTE EYELETS AND CORRESPOND TO POINTS ON P.C. BOARD ASSY. (P/N 402944).

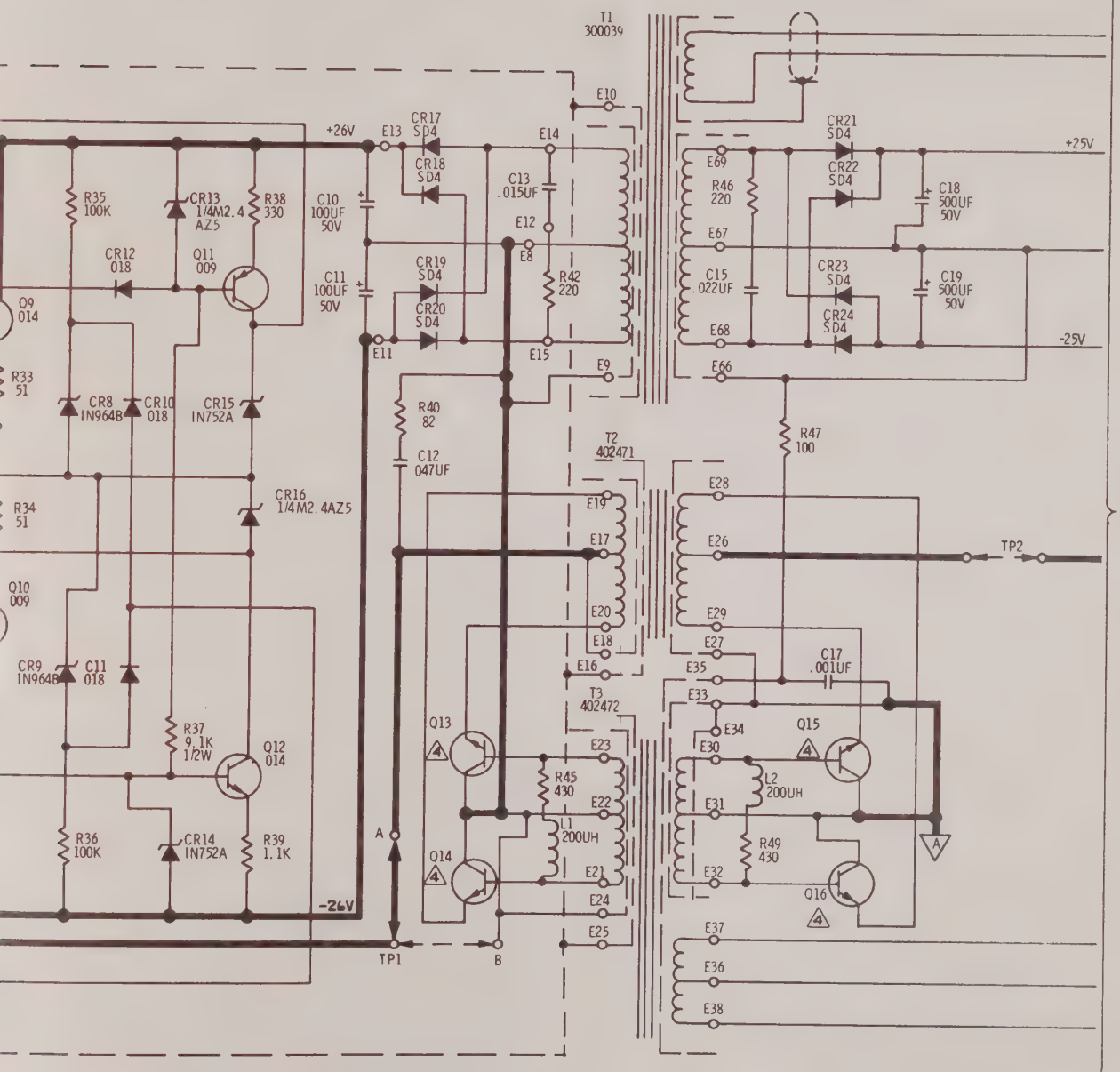
4. TRANSISTORS ARE MATCHED PAIRS:
   Q13 AND Q14 (P/N 200072), Q15 AND Q16 (P/N 200072)
   Q28 AND Q29 (P/N 200074)

3. R55 (GAIN), R60 (ZERO), S1 (GAIN SELECTOR), AND S2 (BANDWIDTH SELECTOR), ARE FRONT PANEL CONTROLS

2. HIGHEST REFERENCE DESIGNATORS USED:
   C58 , CR61 L6, Q66, R121, T3, E79

1. ALL RESISTORS ARE IN OHMS, ±5%, 1/4W CARBON.

NOTES: UNLESS OTHERWISE SPECIFIED

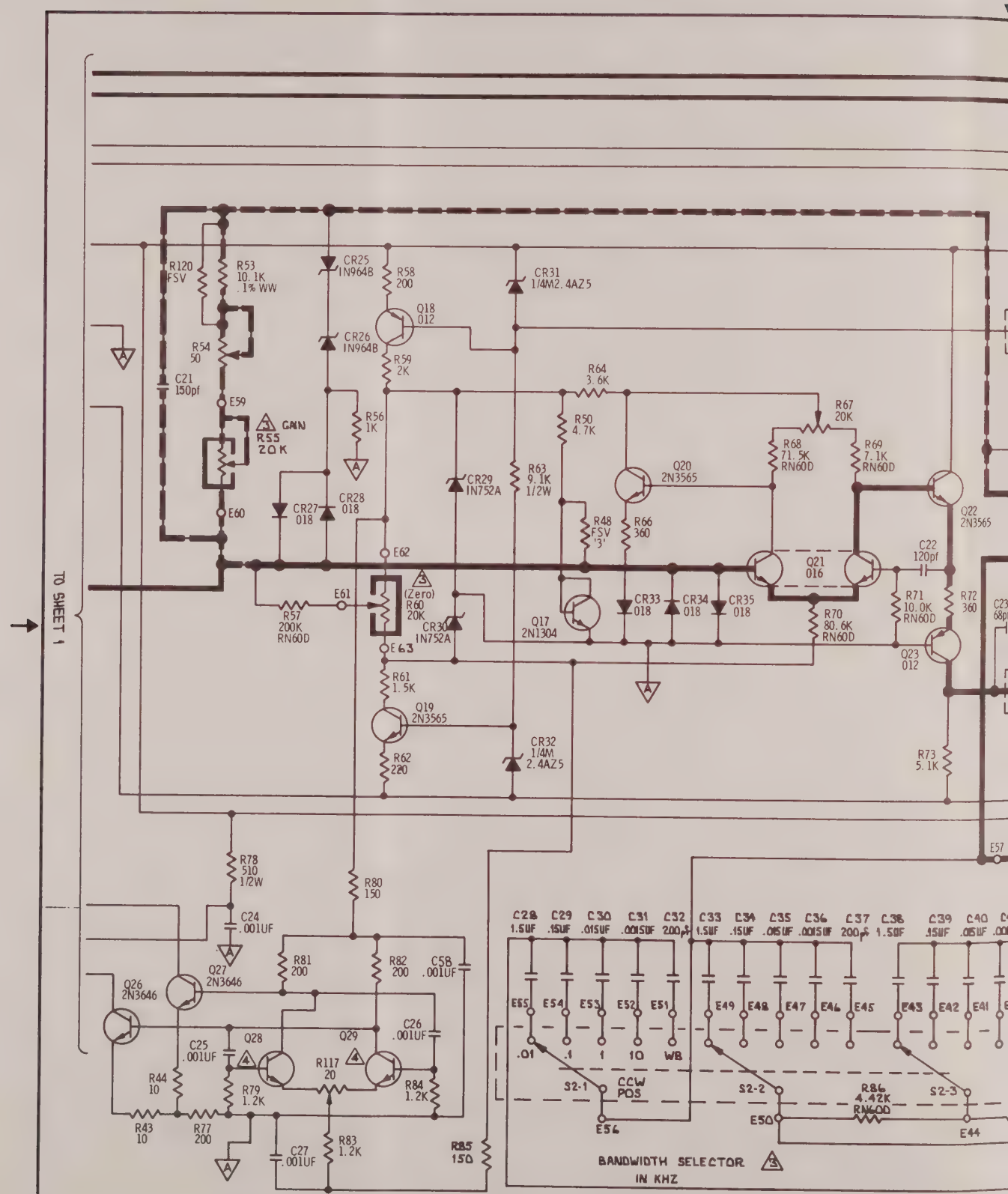


DANA LABORATORIES INC.
IRVINE, CALIFORNIA

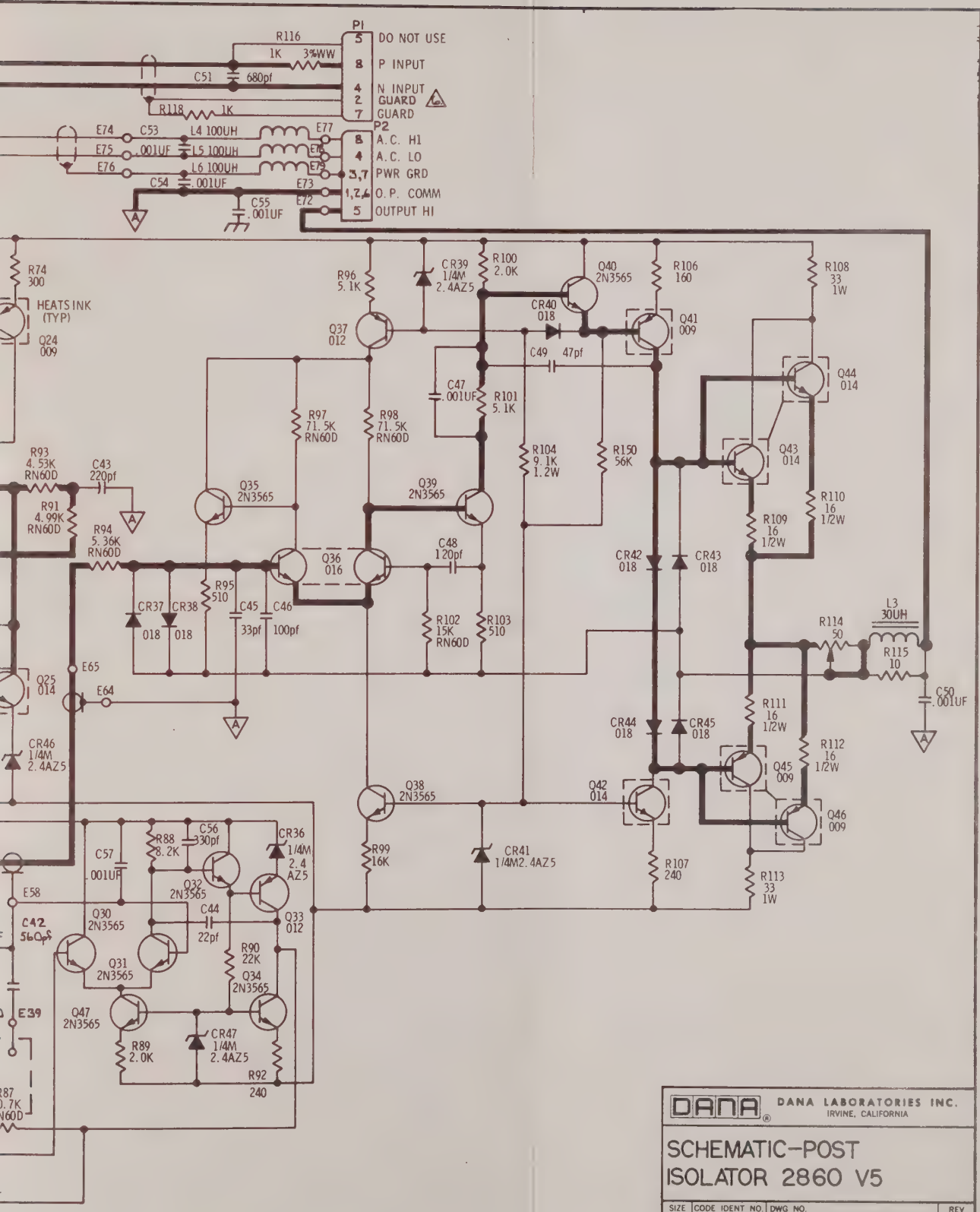
SCHEMATIC-POST ISOLATOR 2860 V5

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	430785	N

SCALE — SHEET OF 2



NOTES: UNLESS OTHERWISE SPECIFIED



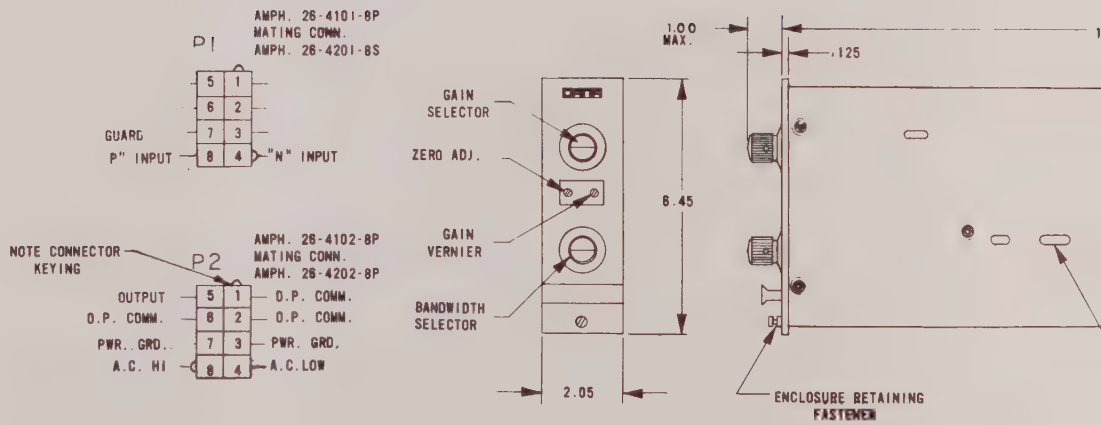
DANA LABORATORIES INC.
IRVINE, CALIFORNIA

SCHEMATIC–POST ISOLATOR 2860 V5

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	430785	N

SCALE —

SHEET 2 OF 2

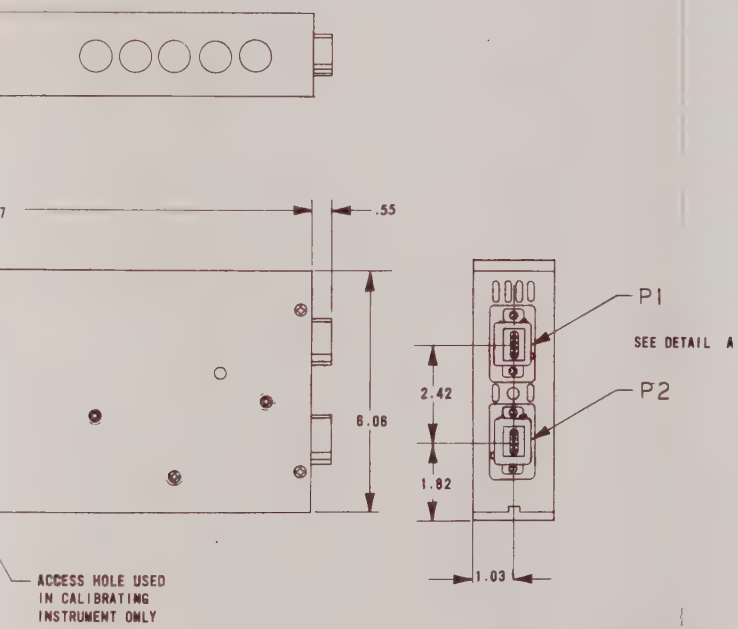


DETAIL 'A'

WIRING TYPICAL OF
DANA CORD SET
NO.402488 AND DANA
MODEL 2808-1 AND
2808-2 ENCLOSURE

NOTE: UNLESS OTHERWISE SPECIFIED

REVISIONS				
LTR	DESCRIPTION	DR	CHK	APPD



QTY REQD	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SPECIFICATION OR VENDOR P/N	ITEM NO.
		LIST OF MATERIAL OR PARTS LIST			

402474	2860		
NEXT ASSY	USED ON	NA	FA
APPLICATION		QTY REQD	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS: X .030, XX .020, XXX .010 | ANGLES 0° 30' | FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

DRAWN	J. M. Edwards	9/10/67
CHECK		
DESIGN	V. F. Solberg	9/10/67
PROJ ENGR	J. Boss	9/9/67
DRN RELEASE	Raymond	10/10/67

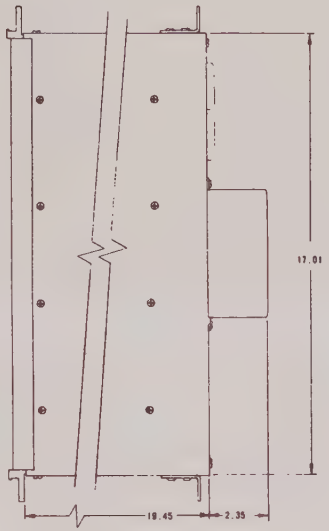
A-19-67 CK

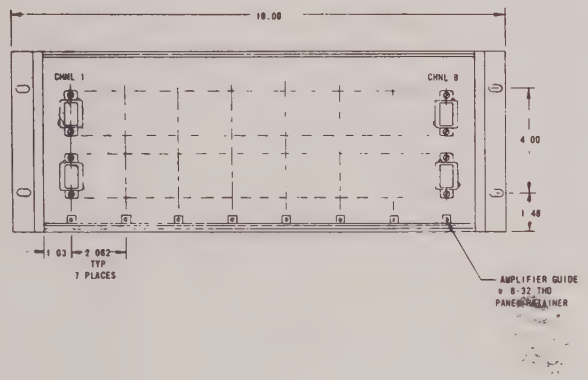
DANA LABORATORIES INC.
IRVINE, CALIFORNIA

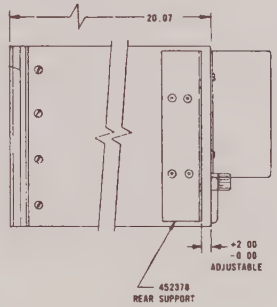
OUTLINE DIMENSIONAL - AMPLIFIER MODEL 2860

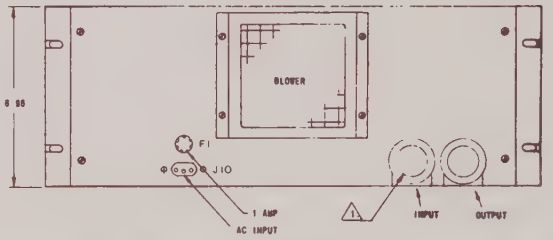
SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	452648	

SCALE 1/2 | WT | SHEET 1 OF 1









QTY REQD	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SPECIFICATION OR VENDOR P/N	ITEM NO.

LIST OF MATERIAL OR PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS: .XX ±.03, .XXX ±.010 | ANGLES 0° 30' | FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

DRAWN	G WILSON	6/2/67
CHECK		
COST ENGR		6/20/67
PROJ ENGR		6/21/67

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

OUTLINE DIMENSIONAL
ENCLOSURE
MODEL 2808-1

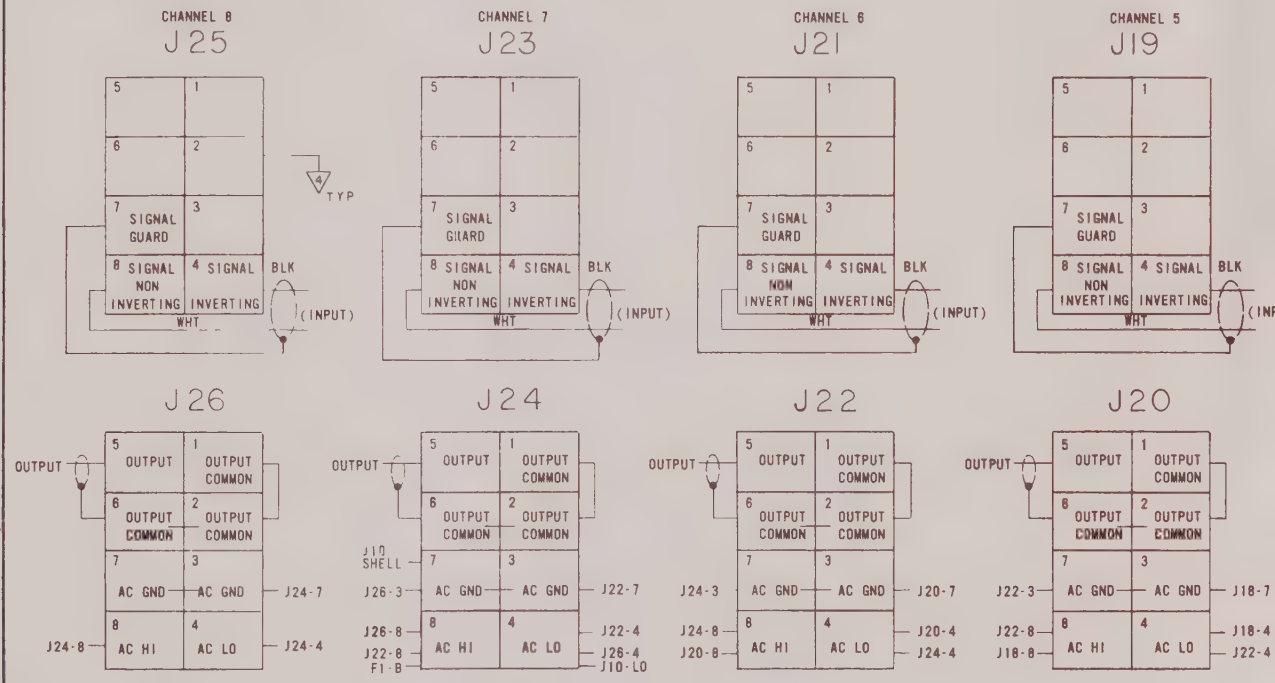
SIZE D | CAGE NUMBER 21793 | DWG NO. 452402

SCALE 1/2 | WT | SHEET 1 OF 1

402368	2808-1	REF	REF
NEXT ASSY	USED ON	MA	FA
APPLICATION		QTY REQD	

⚠ ENCLOSURE WIRING PER DANA DRAWING # 430590.

NOTE: UNLESS OTHERWISE SPECIFIED



4 PIN 2 TIED TO GROUND LUG MOUNTED ON CONNECTORS J11, 13, 15, 17, 19, 21, 23 AND J25 USING 524000 WIRE.

3. INTERCONNECTIONS ON CONNECTORS USING 500004 WIRE AND 501376 SLEEVING AS REQUIRED.

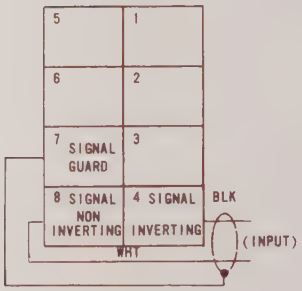
2 ALL AC POWER WIRING TO BE TWISTED.

1. WIRE PER DANA WORKMANSHIP AND PROCEDURE STANDARDS.

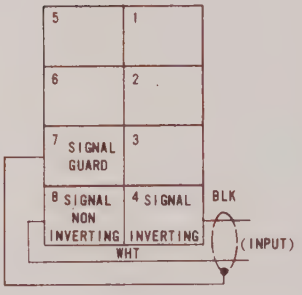
NOTE: UNLESS OTHERWISE SPECIFIED

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REVISED PER EO...2048	10 NOV 1967	
B	REVISED PER E.O. 2118, REROUTE POWER LINE TO J24 WAS TO J12	12/18/67 PECHAL	12/9/67
C	REVISED PER E.O 2199	JA 12-26-67	1/4/68

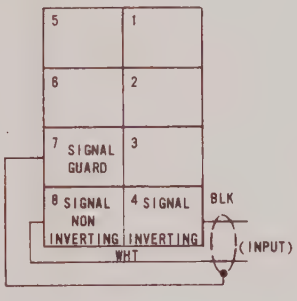
CHANNEL 4
J17



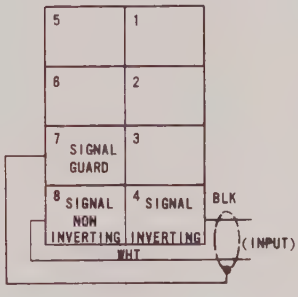
CHANNEL 3
J15



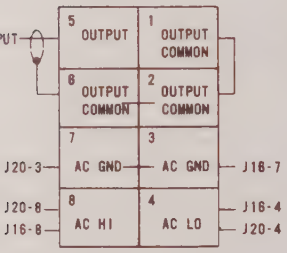
CHANNEL 2
J13



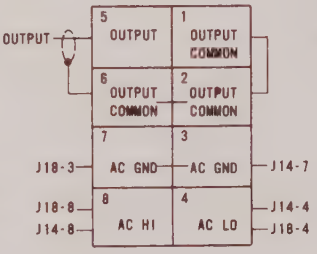
CHANNEL 1
J11



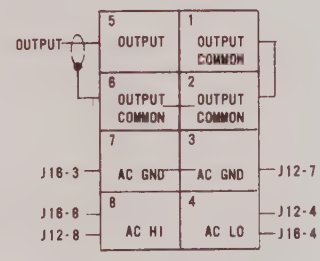
J18



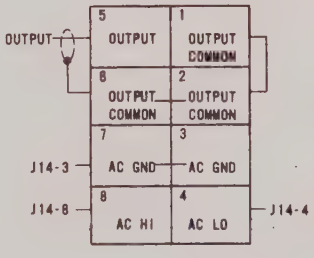
J16



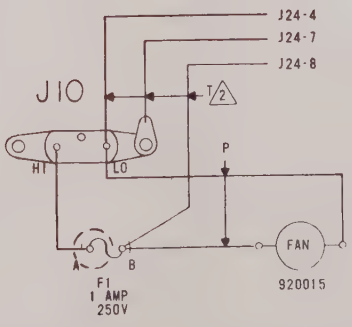
J14



J12



J10



QTY REQD	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SPECIFICATION OR VENDOR P/N	ITEM NO.

LIST OF MATERIAL OR PARTS LIST

402388	2808-1	REF	REF
NEXT ASSY	USED ON	NA	FA
APPLICATION		QTY REQD	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
DECIMALS: X .030, XX .020, XXX .010 | ANGLES 0° 30' | FORMED ANGLES 1.0

MATERIAL

FINISH

CONTRACT NO.

DRAWN A BBOTT 11/9/67
CHECK
COG. ENGR
PROJ ENGR

DRN # 618

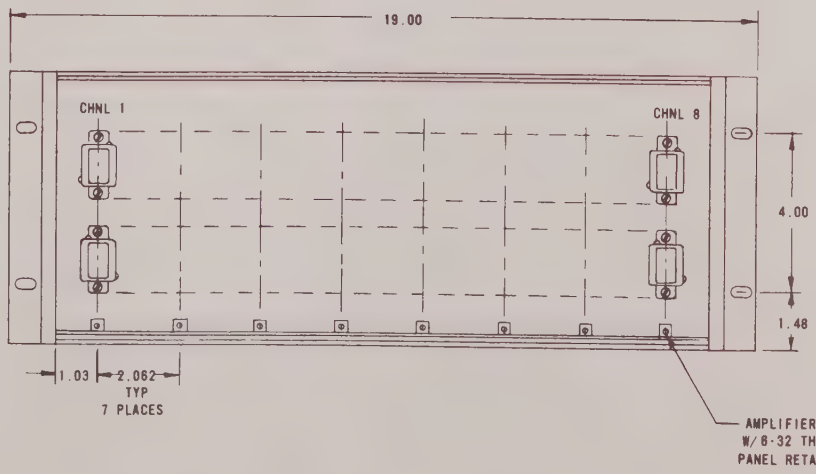
DANA LABORATORIES INC.
IRVINE, CALIFORNIA

WIRING DIAGRAM — 2808 ENCLOSURE, OPT. 1

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	430590	C

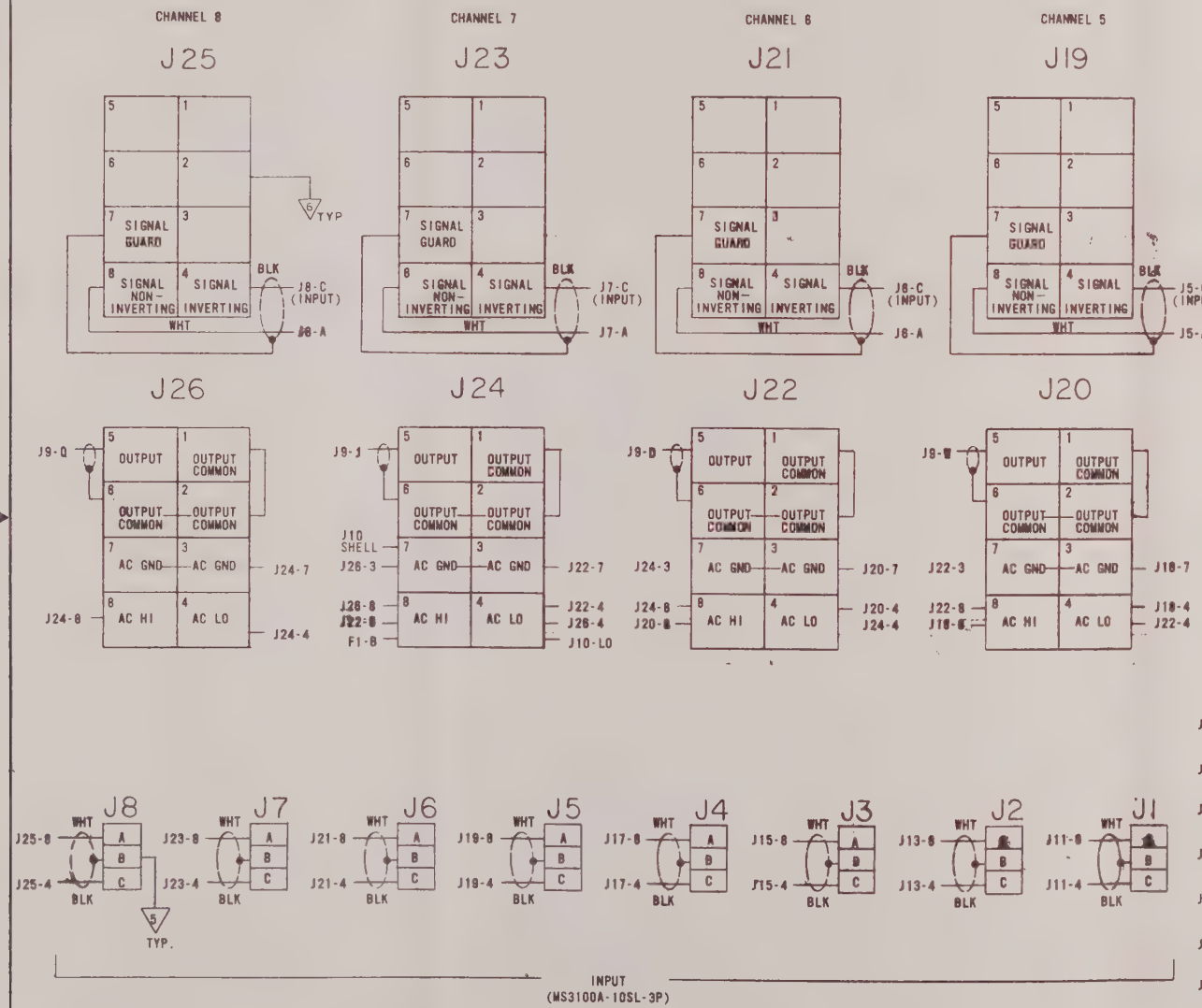
SCALE NONE | WT | SHEET 1 OF 1

REV A P.S. 12/4/67
REV B P.S. 12/8/67



1. ENCLOSURE WIRING PER DANA DRAWING # 430591.

NOTE: UNLESS OTHERWISE SPECIFIED



4. PIN 2 TIED TO GROUND LUG MOUNTED ON CONNECTORS J11, J3, J5, J7, J9, 21, 23, AND J25 USING .524000 WIRE.

5. PIN B ON J1 THRU J8 TO BE TIED TO GROUND LUG MOUNTED ON CONN SHELL USING 500002 WIRE.

4. INTERCONNECTIONS ON CONNECTORS USING 500004 WIRE AND 501376 SLEEVING AS REQUIRED.

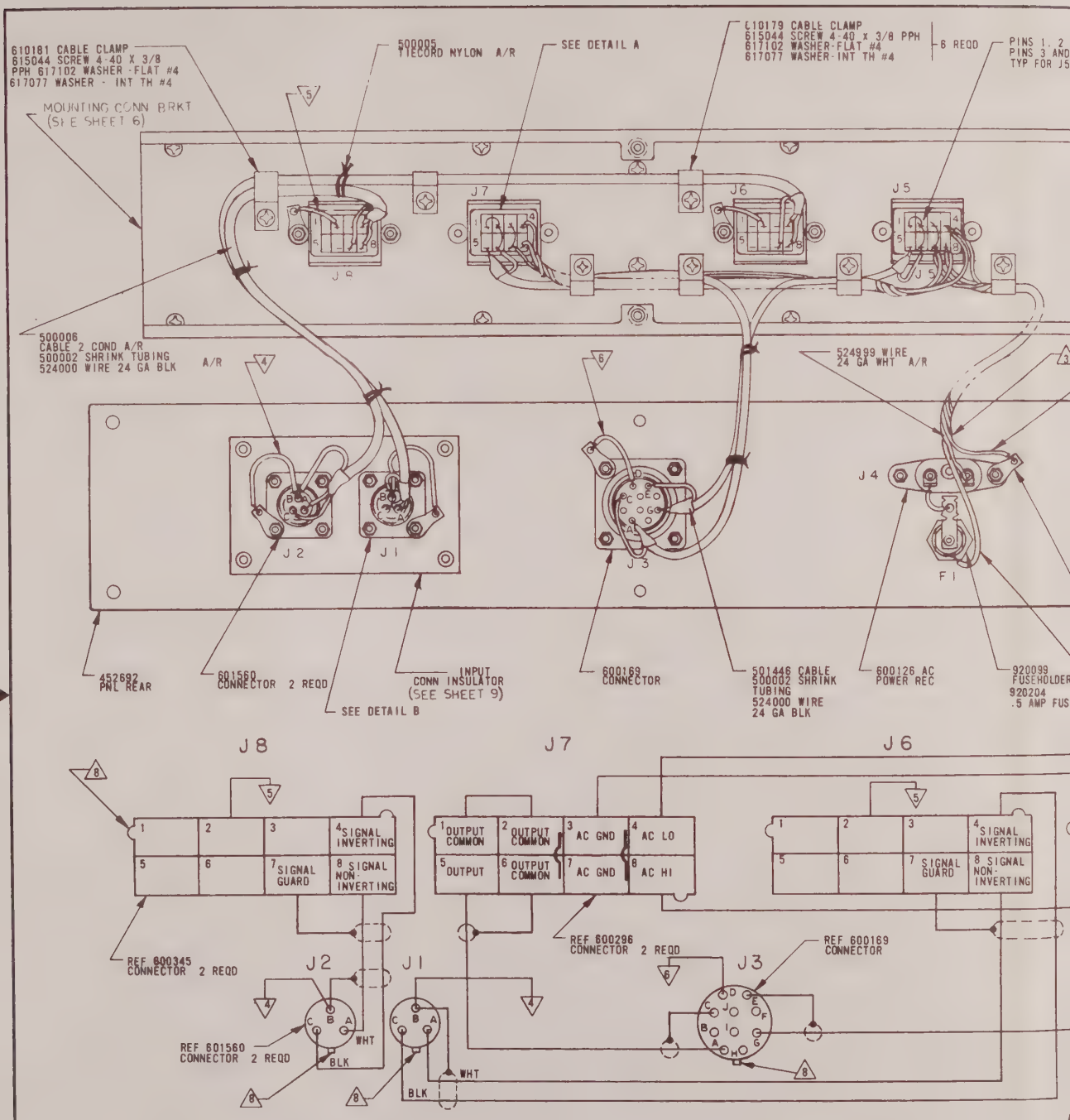
3. ALL AC POWER WIRING TO BE TWISTED.

2. ROUTE AND TIE HARNESSES AND OTHER WIRING PERMITTING REAR PANEL TO OPEN APPROXIMATELY 120°. USE CLAMPS AS REQUIRED TO KEEP CABLES CLEAR OF OPENING ON CONNECTOR MOUNTING BRACKET.

1. WIRE PER DANA WORKMANSHIP AND PROCEDURE STANDARDS.

NOTE: UNLESS OTHERWISE SPECIFIED

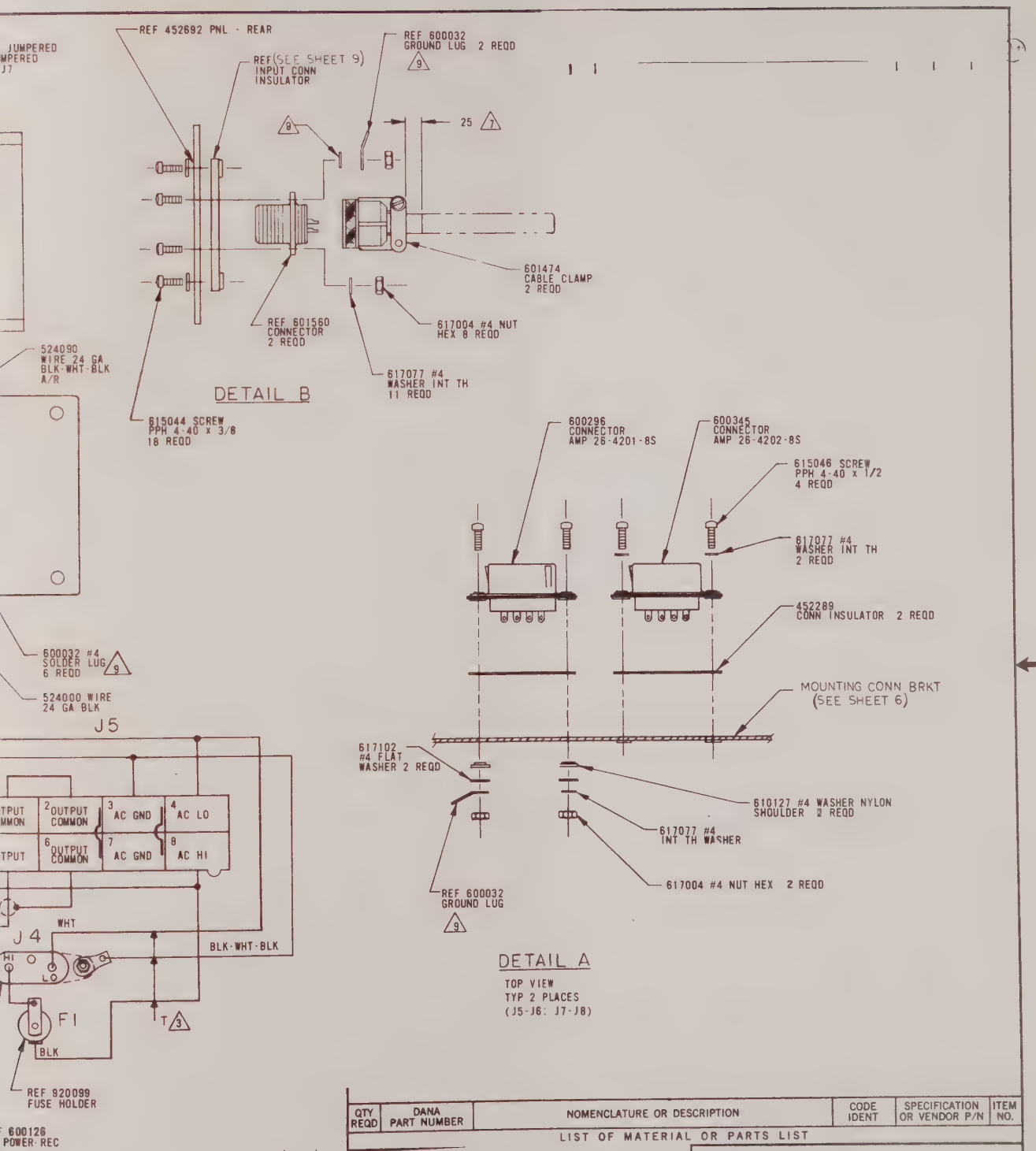
CLEARPRINT 1000H-30



1. RUBBER GROMMET TO BE CUT OFF AS SHOWN BEFORE ASSEMBLY
8. PIN D ON J3 TO BE TIED TO GROUND LUG MOUNTED ON CONNECTOR SHELL USING 500043 WIRE
5. PIN 2 ON J6 TO BE TIED TO GROUND LUG MOUNTED ON CONNECTOR SHELL USING 500043 WIRE
4. PIN B ON J1 TO BE TIED TO GROUND LUG MOUNTED ON CONNECTOR SHELL USING 500043 WIRE
3. ALL A.C. POWER WIRING TO BE TWISTED
2. ROUTE AND TIE HARNESSES AND OTHER WIRING APPROX AS SHOWN TO PERMIT REAR PANEL TO LAY OPEN FOR WIRING
1. WIRE PER DANA WORKMANSHIP AND PROCEDURE STANDARDS

NOTE: UNLESS OTHERWISE SPECIFIED

9. LOCKWASHER NOT USED WITH GROUND LUG P/N 600032
8. CONNECTOR SHELLS ARE KEYED AS INDICATED



QTY REQD	DANA PART NUMBER	NOMENCLATURE OR DESCRIPTION	CODE IDENT	SPECIFICATION OR VENDOR P/N	ITEM NO.

LIST OF MATERIAL OR PARTS LIST

DANA LABORATORIES INC.
IRVINE, CALIFORNIA

ENCLOSURE ASSY - MODEL 2802-2

SIZE	CODE IDENT NO.	DWG NO.	REV
D	21793	402948	C

SCALE | WT | SHEET 3 OF 12

PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION			
CR01	**210015**	DIODE		**HP**	**HP5082-2800**
CR02	**210015**	DIODE		**HP**	**HP5082-2800**
CR03	211083	DIODE SILICO 018	1	DANA	211083
CR04	211083	DIODE SILICO 018	1	DANA	211083
CR05	211083	DIODE SILICO 018	1	DANA	211083
CR06	211083	DIODE SILICO 018	1	DANA	211083
CR07	211083	DIODE SILICO 018	1	DANA	211083
CR08	220016	DIODE SILICO ZENER 1N964B		MOTOROLA	1N964B
CR09	220016	DIODE SILICO ZENER 1N964B		MOTOROLA	1N964B
CR10	211083	DIODE SILICO 018	1	DANA	211083
CR11	211083	DIODE SILICO 018	1	DANA	211083
CR12	211083	DIODE SILICO 018	1	DANA	211083
CR13	**221177**	DIODE SILICO ZENER 1/4M2.4AZ5		MOTOROLA	1/4M2.4AZ5
CR14	220019	DIODE SILICO ZENER 1N752A		MOTOROLA	1N752A
CR15	220019	DIODE SILICO ZENER 1N752A		MOTOROLA	1N752A
CR16	**221177**	DIODE SILICO ZENER 1/4M2.4AZ5		MOTOROLA	1/4M2.4AZ5
CR17	210004	DIODE SILICO SD4		DIODES IN	SD4
CR18	210004	DIODE SILICO SD4		DIODES IN	SD4
CR19	210004	DIODE SILICO SD4		DIODES IN	SD4
CR20	210004	DIODE SILICO SD4		DIODES IN	SD4
CR21	210004	DIODE SILICO SD4		DIODES IN	SD4
CR22	210004	DIODE SILICO SD4		DIODES IN	SD4
CR23	210004	DIODE SILICO SD4		DIODES IN	SD4
CR24	210004	DIODE SILICO SD4		DIODES IN	SD4
CR25	220016	DIODE SILICO ZENER 1N964B		MOTOROLA	1N964B
CR26	220016	DIODE SILICO ZENER 1N964B		MOTOROLA	1N964B
CR27	211083	DIODE SILICO 018	1	DANA	211083
CR28	211083	DIODE SILICO 018	1	DANA	211083
CR29	220019	DIODE SILICO ZENER 1N752A		MOTOROLA	1N752A
CR30	220019	DIODE SILICO ZENER 1N752A		MOTOROLA	1N752A
CR31	**221177**	DIODE SILICO ZENER 1/4M2.4AZ5		MOTOROLA	1/4M2.4AZ5
CR32	**221177**	DIODE SILICO ZENER 1/4M2.4AZ5		MOTOROLA	1/4M2.4AZ5
CR33	211083	DIODE SILICO 018	1	DANA	211083
CR34	211083	DIODE SILICO 018	1	DANA	211083
CR35	211083	DIODE SILICO 018	1	DANA	211083
CR36	**221177**	DIODE SILICO ZENER 1/4M2.4AZ5		MOTOROLA	1/4M2.4AZ5
CR37	211083	DIODE SILICO 018	1	DANA	211083
CR38	211083	DIODE SILICO 018	1	DANA	211083

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PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION						
CR39	221177	DIODE SILICO ZENER 1/4M2.4AZ5					MOTOROLA	1/4M2.4AZ5
CR40	211083	DIODE SILICO	018			1	DANA	211083
CR41	221177	DIODE SILICO ZENER 1/4M2.4AZ5					MOTOROLA	1/4M2.4AZ5
CR42	211083	DIODE SILICO	018			1	DANA	211083
CR43	211083	DIODE SILICO	018			1	DANA	211083
CR44	211083	DIODE SILICO	018			1	DANA	211083
CR45	211083	DIODE SILICO	018			1	DANA	211083
CR46	221177	DIODE SILICO ZENER 1/4M2.4AZ5					MOTOROLA	1/4M2.4AZ5
CR47	221177	DIODE SILICO ZENER 1/4M2.4AZ5					MOTOROLA	1/4M2.4AZ5
C01	121473	CAP MYLAR	.0015 MFD	100 V	10%1		CDE	WMF1S47
C02	100012	CAP CERAM	33 PFD	500 V	10%		AEROVOX	TCD-N750
C03	101174	CAP CERAM	.001 MFD	500 V	10%1		AEROVOX	SCD3X5F
C04	100012	CAP CERAM	33 PFD	500 V	10%		AEROVOX	TCD-N750
C05	101175	CAP CERAM	220 PFD	500 V	10%1		AEROVOX	SCD1X5F
C07	101641	CAP CERAM	470 PFD	500 V	10%1		AEROVOX	SCD1X5F
C10	110061	CAP ELECT	100 MFD	50 V			SPRAGUE	39D107G050EJ4
C11	110061	CAP ELECT	100 MFD	50 V			SPRAGUE	39D107G050EJ4
C12	121093	CAP MYLAR	.047 MFD	100 V	10%1		CDE	WMF1S47
C13	120131	CAP MYLAR	.015 MFD	100 V	5%	IMB		XT2B153J
C15	121468	CAP MYLAR	.022 MFD	100 V	10%1		CDE	WMF1S22
C17	101174	CAP CERAM	.001 MFD	500 V	10%1		AEROVOX	SCD3X5F
C18	110062	CAP ELECT	500 MFD	50 V			SPRAGUE	39D507G050L4
C19	110062	CAP ELECT	500 MFD	50 V			SPRAGUE	39D507G050L4
C21	101145	CAP CERAM	100 PFD		10%		AEROVOX	ETCD-DI-1(N5600)
C22	100018	CAP CERAM	120 PFD	1000 V	10%	AEROVOX	ETCD	
C23	100010	CAP CERAM	68 PFD	500 V	10%	AERVOX	TCD-N750	
C24	101174	CAP CERAM	.001 MFD	500 V	10%1		AEROVOX	SCD3X5F
C25	101174	CAP CERAM	.001 MFD	500 V	10%1		AEROVOX	SCD3X5F
C26	101174	CAP CERAM	.001 MFD	500 V	10%1		AEROVOX	SCD3X5F
C27	101174	CAP CERAM	.001 MFD	500 V	10%1		AEROVOX	SCD3X5F
C28	120129	CAP MYLAR	1.5 MFD	100 V	5%	IMB		XT2B155J
C29	120130	CAP MYLAR	.15 MFD	100 V	5%	IMB		XT2B154J
C30	120131	CAP MYLAR	.015 MFD	100 V	5%	IMB		XT2B153J
C31	130051	CAP GLASS	.0015 MFD		5%	ELMENCO		CM-20-E-152J
C32	130056	CAP GLASS	200 PFD		5%	OHMITE		CM15E201J
C33	120129	CAP MYLAR	1.5 MFD	100 V	5%	IMB		XT2B155J
C34	120130	CAP MYLAR	.15 MFD	100 V	5%	IMB		XT2B154J
C35	120131	CAP MYLAR	.015 MFD	100 V	5%	IMB		XT2B153J

FORM NO. 10110-P

FC4198

PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION						
C36	130051	CAP	GLASS	.0015 MFD		5%	ELMENCO	CM-20-E-152J
C37	130056	CAP	GLASS	200 PFD		5%	OHMITE	CM15E201J
C38	120129	CAP	MYLAR	1.5 MFD	100 V	5%	IMB	XT2B155J
C39	120130	CAP	MYLAR	.15 MFD	100 V	5%	IMB	XT2B154J
C40	120131	CAP	MYLAR	.015 MFD	100 V	5%	IMB	XT2B153J
C41	130051	CAP	GLASS	.0015 MFD		5%	ELMENCO	CM-20-E-152J
C42	130057	CAP	GLASS	560 PFD		5%	OHMITE	CM15E561J
C43	101175	CAP	CERAM	220 PFD	500 V	10%1	AEROVOX	SCD1X5F
C44	100005	CAP	CERAM	22 PFD	500 V	10%	AEROVOX	TCD-N750
C45	100012	CAP	CERAM	33 PFD	500 V	10%	AEROVOX	TCD-N750
C46	101145	CAP	CERAM	100 PFD	500 V	10%1	AEROVOX	SCD1X5F
C47	101174	CAP	CERAM	.001 MFD	500 V	10%1	AEROVOX	SCD3X5F
C48	100018	CAP	CERAM	120 PFD	1000 V	10%	AEROVOX	ETCD
C49	101182	CAP	CERAM	47 PFD	500 V	10%1	AEROVOX	TCD-N750
C50	101174	CAP	CERAM	.001 MFD	500 V	10%1	AEROVOX	SCD3X5F
C51	101099	CAP	CERAM	680 PFD	500 V	10%1	AEROVOX	SCD2X5F
C53	101174	CAP	CERAM	.001 MFD	500 V	10%1	AEROVOX	SCD3X5F
C54	101174	CAP	CERAM	.001 MFD	500 V	10%1	AEROVOX	SCD3X5F
C55	101174	CAP	CERAM	.001 MFD	500 V	10%1	AEROVOX	SCD3X5F
C56	**101098**	**CAP**	**CERAM**	**330 PFD**	**500 V**	**10%1**	**AEROVOX**	**SCD1X5F**
C57	**101174**	**CAP**	**CERAM**	**.001 MFD**	**500 V**	**10%1**	**AEROVOX**	**SCD3X5F**
C58	**101174**	**CAP**	**CERAM**	**.001 MFD**	**500 V**	**10%1**	**AEROVOX**	**SCD3X5F**
L01	310034	CHOKE		200 MH			MILLER	9210-90
L02	310034	CHOKE		200 MH			MILLER	9210-90
L03	402470	**CHOKE OUTPUT**		**30 MH**			**DANA**	**402470**
L04	310033	CHOKE		100 MH			MILLER	9210-76
L05	310033	CHOKE		100 MH			MILLER	9210-76
L06	310033	CHOKE		100 MH			MILLER	9210-76
Q01	201084	TRANS	GERMAN PNP	2N1304		1	TI	2N1304
Q02	402715	ASSY		FSV 2860			DANA	402715
Q03	201285	TRANS	DUAL NPN	016S			DANA	201285
Q04	200043	TRANS	SILICO NPN	2N3565			FAIRCHILD	2N3565
Q05	200043	TRANS	SILICO NPN	2N3565			FAIRCHILD	2N3565
Q06	200043	TRANS	SILICO NPN	2N3565			FAIRCHILD	2N3565
Q07	200011	TRANS	SILICO PNP	009			DANA	200011
Q08	200035	TRANS	SILICO NPN	014			DANA	200035
Q09	200035	TRANS	SILICO NPN	014			DANA	200035
Q10	200011	TRANS	SILICO PNP	009			DANA	200011
Q11	200011	TRANS	SILICO PNP	009			DANA	200011

FORM NO. 10110-P

PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION					
Q12	200035	TRANS SILICO NPN	014		DANA	200035	
Q13	200072	TRANS SILICO DUAL FSV			DANA	200072	
Q14	200072	TRANS SILICO DUAL FSV			DANA	200072	
Q15	200072	TRANS SILICO DUAL FSV			DANA	200072	
Q16	200072	TRANS SILICO DUAL FSV			DANA	200072	
Q17	201084	TRANS GERMAN PNP	2N1304	1	TI	2N1304	
Q18	200022	TRANS SILICO PNP	012		DANA	200022	
Q19	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q20	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q21	200040	TRANS SILICO NPN	016		DANA	200040	
Q22	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q23	200022	TRANS SILICO PNP	012		DANA	200022	
Q24	200011	TRANS SILICO PNP	009		DANA	200011	
Q25	200035	TRANS SILICO NPN	014		DANA	200035	
Q26	200037	TRANS SILICO NPN	2N3646		FAIRCHILD	2N3646	
Q27	200037	TRANS SILICO NPN	2N3646		FAIRCHILD	2N3646	
Q28	200074	TRANS SILICO DUAL FSV			DANA	200074	
Q29	200074	TRANS SILICO DUAL FSV			DANA	200074	
Q30	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q31	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q32	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q33	200022	TRANS SILICO PNP	012		DANA	200022	
Q34	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q35	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q36	200040	TRANS SILICO NPN	016		DANA	200040	
Q37	200022	TRANS SILICO PNP	012		DANA	200022	
Q38	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q39	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q40	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q41	200011	TRANS SILICO PNP	009		DANA	200011	
Q42	200035	TRANS SILICO NPN	014		DANA	200035	
Q43	200035	TRANS SILICO NPN	014		DANA	200035	
Q44	200035	TRANS SILICO NPN	014		DANA	200035	
Q45	200011	TRANS SILICO PNP	009		DANA	200011	
Q46	200011	TRANS SILICO PNP	009		DANA	200011	
Q47	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	
Q48	200043	TRANS SILICO NPN	2N3565		FAIRCHILD	2N3565	

FORM NO. 10110-P

F94 1165

PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION							
R01	020386	RES	WW	10 K	.1%	1/8 W	JORDAN	J11	
R02	020436	RES	WW	5 K	.01%		JORDAN	J11	
R03	020435	RES	WW	2 K	.01%		JORDAN	J11	
R04	020434	RES	WW	1 K	.01%		JORDAN	J11	
R05	020433	RES	WW	500 OHM	.01%		JORDAN	J11	
R06	020432	RES	WW	200 OHM	.01%		JORDAN	J11	
R07	020431	RES	WW	100 OHM	.01%		JORDAN	J11	
R08	020430	RES	WW	50 OHM	.01%		JORDAN	J11	
R09	020429	RES	WW	20 OHM	.01%		JORDAN	J11	
R10	020428	RES	WW	10 OHM	.01%		JORDAN	J11	
R11	010336	RES	METAL	806 K	1%		CORNING	RN60D9083F	
R12	010336	RES	METAL	806 K	1%		CORNING	RN60D9083F	
R13	040092	RES	VARI	20 K			SPECTRO	50-3-1-203	
R14	010112	RES	METAL	5.36 K	1%	1/4 W1	ELECTRA	RN60D5361F	
R15	010120	RES	METAL	68.1 K	1%	1/4 W	ELECTRA	RN60D6812F	
R16	040093	RES	VARI	500 OHM			SPECTRO	50-3-1-501	
R17	402715	ASSY		FSV 2860			DANA	402715	
R18	402715	ASSY		FSV 2860			DANA	402715	
R19	010122	RES	METAL	28.7 K	1%	1/4 W	ELECTRA	RN60B2872F	
R20	010259	RES	METAL	1 K	1%	1/4 W	ELECTRA	RN60C1001F	
R21	000102	RES	CARBON	1 K	5%	1/4 W1	OHMITE	RC07GF102J	
R22	000302	RES	CARBON	3 K	5%	1/4 W1	OHMITE	RC07GF302J	
R23	000134	RES	CARBON	130 K	5%	1/4 W	OHMITE	RC07GF134J	
R24	000134	RES	CARBON	130 K	5%	1/4 W	OHMITE	RC07GF134J	
R25	010022	RES	METAL	46.4 K	1%	1/4 W	ELECTRA	RN60D4642F	
R26	000912	RES	CARBON	9.1 K	5%	1/4 W	OHMITE	RC07GF192J	
R27	000153	RES	CARBON	15 K	5%	1/4 W1	OHMITE	RC07GF153J	
R28	000621	RES	CARBON	620 OHM	5%	1/4 W1	OHMITE	RC07GF621J	
R29	000101	RES	CARBON	100 OHM	5%	1/4 W1	OHMITE	RC07GF101J	
R30	000331	RES	CARBON	330 OHM	5%	1/4 W1	OHMITE	RC07GF331J	
R31	000182	RES	CARBON	1.8 K	5%	1/4 W1	OHMITE	RC07GF182J	
R32	000820	RES	CARBON	82 OHM	5%	1/4 W	OHMITE	RC07GF820J	
R33	000510	RES	CARBON	51 OHM	5%	1/4 W1	OHMITE	RC07GF510J	
R34	000510	RES	CARBON	51 OHM	5%	1/4 W1	OHMITE	RC07GF510J	
R35	000104	RES	CARBON	100 K	5%	1/4 W1	OHMITE	RC07GF104J	
R36	000104	RES	CARBON	100 K	5%	1/4 W1	OHMITE	RC07GF104J	
R37	001102	RES	CARBON	9.1 K	5%	1/2 W	OHMITE	RC20GF912J	
R38	000331	RES	CARBON	330 OHM	5%	1/4 W1	OHMITE	RC07GF331J	

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PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION							
R39	000112	RES	CARBON	1.1 K	5%	1/4 W		OHMITE	RC07GF112J
R40	000820	RES	CARBON	82 OHM	5%	1/4 W		OHMITE	RC07GF820J
R42	000221	RES	CARBON	220 OHM	5%	1/4 W1		OHMITE	RC07GF221J
R43	000100	RES	CARBON	10 OHM	5%	1/4 W1		OHMITE	RC07GF100J
R44	000100	RES	CARBON	10 OHM	5%	1/4 W1		OHMITE	RC07GF100J
R45	000431	RES	CARBON	430 OHM	5%	1/4 W1		OHMITE	RC07GF431J
R46	000221	RES	CARBON	220 OHM	5%	1/4 W1		OHMITE	RC07GF221J
R47	000101	RES	CARBON	100 OHM	5%	1/4 W1		OHMITE	RC07GF101J
R48	402715	ASSY		FSV 2860				DANA	402715
R49	000431	RES	CARBON	430 OHM	5%	1/4 W1		OHMITE	RC07GF431J
R50	000472	RES	CARBON	4.7 K	5%	1/4 W1		OHMITE	RC07GF472J
R51	000182	RES	CARBON	1.8 K	5%	1/4 W1		OHMITE	RC07GF182J
R53	020479	RES	WW	10.1 K	.1%			JORDAN	J11
R54	040108	RES	VARI	50 OHM				SPECTROL	50-3
R55	040162	POT	WW	20 K	10-TURN			IRC	5000-20K
R56	000102	RES	CARBON	1 K	5%	1/4 W1		OHMITE	RC07GF102J
R57	010158	RES	METAL	200 K	1%	1/4 W1		ELECTRA	RN60D2003F
R58	000201	RES	CARBON	200 OHM	5%	1/4 W1		OHMITE	RC07GF201J
R59	000202	RES	CARBON	2 K	5%	1/4 W1		OHMITE	RC07GF202J
R60	040040	RES	VARI	20 K	10%	1/4 W		BOURNS	271-1-203 M
R61	000152	RES	CARBON	1.5 K	5%	1/4 W1		OHMITE	RC07GF152J
R62	000221	RES	CARBON	220 OHM	5%	1/4 W1		OHMITE	RC07GF221J
R63	001102	RES	CARBON	9.1 K	5%	1/2 W		OHMITE	RC20GF912J
R64	000362	RES	CARBON	3.6 K	5%	1/4 W1		OHMITE	RC07GF362J
R66	000361	RES	CARBON	360 OHM	5%	1/4 W		OHMITE	RC07GF361J
R67	040092	RES	VARI	20 K				SPECTRO	50-3-1-203
R68	010075	RES	METAL	71.5 K	1%	1/4 W		ELECTRA	RN60D7152F
R69	010075	RES	METAL	71.5 K	1%	1/4 W		ELECTRA	RN60D7152F
R70	010077	RES	METAL	80.6 K	1%	1/4 W		ELECTRA	RN60D8062F
R71	010060	RES	METAL	10 K	1%	1/4 W		ELECTRA	RN60D1002F
R72	000361	RES	CARBON	360 OHM	5%	1/4 W		OHMITE	RC07GF361J
R73	000512	RES	CARBON	5.1 K	5%	1/4 W1		OHMITE	RC07GF512J
R74	000301	RES	CARBON	300 OHM	5%	1/4 W		OHMITE	RC07GF301J
R77	000201	RES	CARBON	200 OHM	5%	1/4 W1		OHMITE	RC07GF201J
R78	001706	RES	CARBON	510 OHM	5%	1/2 W1		OHMITE	RC20GF511J
R79	000122	RES	CARBON	1.2 K	5%	1/4 W1		OHMITE	RC07GF122J
R80	000151	RES	CARBON	150 OHM	5%	1/4 W1		OHMITE	RC07GF151J

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PARTS LIST

ASSEMBLY 402944 **P C BOARD ASSY. MODEL 2860 OPT V5**

REF. DESIG.	PART NO.	DESCRIPTION							
R81	000201	RES	CARBON	200	OHM	5%	1/4 W1	OHMITE	RC07GF201J
R82	000201	RES	CARBON	200	OHM	5%	1/4 W1	OHMITE	RC07GF201J
R83	000122	RES	CARBON	1.2	K	5%	1/4 W1	OHMITE	RC07GF122J
R84	000122	RES	CARBON	1.2	K	5%	1/4 W1	OHMITE	RC07GF122J
R85	000151	RES	CARBON	150	OHM	5%	1/4 W1	OHMITE	RC07GF151J
R86	010211	RES	METAL	4.42	K	1%		CORNING	RN60D
R87	010324	RES	METAL	10.7	K	1%		CORNING	RN60D1072F
R88	000822	RES	CARBON	8.2	K	5%	1/4 W1	OHMITE	RC07GF822J
R89	000202	RES	CARBON	2	K	5%	1/4 W1	OHMITE	RC07GF202J
R90	000223	RES	CARBON	22	K	5%	1/4 W	OHMITE	RC07GF223J
R91	010020	RES	METAL	4.99	K	1%	1/4 W	ELECTRA	RN60D4991F
R92	000241	RES	CARBON	240	OHM	5%	1/4 W1	OHMITE	RC07GF241J
R93	010085	RES	METAL	4.53	K	1%	1/4 W	ELECTRA	RN60D4531F
R94	010112	RES	METAL	5.36	K	1%	1/4 W1	ELECTRA	RN60D5361F
R95	000511	RES	CARBON	510	OHM	5%	1/4 W1	OHMITE	RC07GF511J
R96	000512	RES	CARBON	5.1	K	5%	1/4 W1	OHMITE	RC07GF512J
R97	010075	RES	METAL	71.5	K	1%	1/4 W	ELECTRA	RN60D7152F
R98	010075	RES	METAL	71.5	K	1%	1/4 W	ELECTRA	RN60D7152F
R99	000163	RES	CARBON	16	K	5%	1/4 W1	OHMITE	RC07GF163J
R100	000202	RES	CARBON	2	K	5%	1/4 W1	OHMITE	RC07GF202J
R101	000512	RES	CARBON	5.1	K	5%	1/4 W1	OHMITE	RC07GF512J
R102	010113	RES	METAL	15	K	1%	1/4 W	ELECTRA	RN60D1502F
R103	000511	RES	CARBON	510	OHM	5%	1/4 W1	OHMITE	RC07GF511J
R104	001102	RES	CARBON	9.1	K	5%	1/2 W	OHMITE	RC20GF912J
R105	000563	RES	CARBON	56	K	5%	1/4 W	OHMITE	RC07GF563J
R106	000161	RES	CARBON	160	OHM	5%	1/4 W	OHMITE	RC07GF161J
R107	000241	RES	CARBON	240	OHM	5%	1/4 W1	OHMITE	RC07GF241J
R108	001751	RES	CARBON	33	OHM	5%	1/2 W	OHMITE	RC20GF330J
R109	001748	RES	CARBON	16	OHM	5%	1/2 W	OHMITE	RC20GF160J
R110	001748	RES	CARBON	16	OHM	5%	1/2 W	OHMITE	RC20GF160J
R111	001748	RES	CARBON	16	OHM	5%	1/2 W	OHMITE	RC20GF160J
R112	001748	RES	CARBON	16	OHM	5%	1/2 W	OHMITE	RC20GF160J
R113	001751	RES	CARBON	33	OHM	5%	1/2 W	OHMITE	RC20GF330J
R114	040052	RES	VARI	50	OHM	10%	1.5 W	CTS	110
R115	000100	RES	CARBON	10	OHM	5%	1/4 W1	OHMITE	RC07GF100J
R116	020381	RES	WW	1	K	3%	3 W	CF	M18
R117	040098	RES	VARI	20	K	10%		BECKMAN	62PR20K
R118	000102	RES	CARBON	1	K	5%	1/4 W1	OHMITE	RC07GF102J

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REF. DESIG.	PART NO.	DESCRIPTION							
R119	000161	RES	CARBON	160	OHM	5%	1/4 W	OHMITE	RC07GF161J
R120	402715	ASSY			FSV 2860			DANA	402715
R121	600245	Jumper						GETTIG	L-2007-1

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